# XXXII.—*The Canonbie Coalfield: its Geological Structure and Relations to the Carboniferous Rocks of the North of England and Central Scotland.*

By B. N. Peach, LL.D., F.R.S., and J. Horne, LL.D., F.R.S. (With Four Plates.)*

(Read June 15, 1903. Given in for publication November 11, 1903. Issued separately December 31, 1903.)

CONTENTS.



## I. Previous Researches.

The Canonbie Coalfield occupies a small tract of ground between the Liddel Water and the river Esk in the south-east part of the county of Dumfries. Though of limited extent, the coalfield has aroused considerable interest, due partly to the important series of plants obtained from the beds, and partly to the questions bearing on the correlation of the Carboniferous rocks of the Scottish Border with those in the North of England and Central Scotland.

In 1861 an elaborate paper, with numerous sections and a geological map, was communicated by Mr Edmund Gibsone to the North of England Institute of Mining Engineers on "The Border Districts of Dumfriesshire, Cumberland, and Part of Roxburghshire, including the Coal Formation of Canonbie."† The following classification of the Carboniferous rocks was adopted by the author. (1) The Carboniferous Limestone, comprising a lower series of sandstones, shales, and thin limestones, and an upper series consisting of thick limestones (Peterscrook, Harelaw Hill, Springkell, and

* Communicated by permission of the Director of H.M. Geological Survey.

† *Trans. North of England Inst. of Mining Engineers*, vol. xi. p. 65, 1861–2.

Kelhead), sandstones, black and blue shales, with numerous seams of coal, from a few inches to two feet thick. (2) The Coal Formation, including a lower group of sandstones and shales (Millstone Grit) underlying the Byre Burn coal-seams, and an upper group embracing the workable coal-seams of Rowanburn. In the geological map accompanying this paper, and in the descriptive notes, all the red sandstones lying to the south of the foregoing subdivisions are regarded as of Permian age; the boundary line between the two systems being a fault, which is referred to as "the great Permian Fault."

In 1863 an important advance in the classification of the Carboniferous rocks of the Canonbie district was made by Mr E. W. Binney, in a paper contributed to the Literary and Philosophical Society of Manchester on "Further Observations on the Carboniferous, Permian, and Triassic Strata of Cumberland and Dumfries."* While accepting Mr Gibsone's correlation of the Byre Burn and Rowanburn coal-bearing strata with the Coal-measures, he differed from him in regarding all the red sandstones to the south of the so-called great Permian fault as of Permian age. He contended that some of the red sandstones, as for instance those visible in the Esk north of Canonbie bridge, and in the Liddel south of Penton, belong to Upper Coal-measures. His reasons for this view were "that in their physical characters they are more like Carboniferous than Permian deposits, and that they contain the *Spirorbis* limestone, *Stigmaria ficoides*, and other Coal plants." Immediately to the north of Canonbie bridge, in certain red shales exposed in the Esk, Mr Binney found rootlets of *Stigmaria ficoides*, which deposits were regarded by him as "the highest Coal-measures ever yet noticed in Great Britain." Again, further up the river, at the Knotty Holm, he obtained plant-remains from a mottled sandstone, which he referred to *Calamites approximatus* and *Dadoxylon*. Still northwards in this section, but to the south of the great Permian fault defined by Mr Gibsone, he noted a thin bed of limestone, six inches thick, in red and purple shales and clays, containing *Spirorbis carbonarius* and a *Cypris*? In view of this evidence, and on the assumption that the red sandstones of the Upper Coal-measures and the Middle Coal-measures of Byre Burn and Rowanburn are comformable, Mr Binney estimated that a bore sunk at Canonbie bridge would have to pass through from 350 to 400 fathoms of strata before reaching the workable coal-seams of Canonbie. This estimate is of special interest in the light of the bores put down in recent years by His Grace the Duke of Buccleuch, to which reference will be made in the sequel.

At a later date Mr Binney revisited the Canonbie district with his friend Mr J. W. Kirkby, when he obtained further evidence in support of his correlation of some of the red sandstones of the Esk and the Liddel with the Upper Coal-measures.†

In 1876 the Geological Survey began the mapping of the Carboniferous tract of the Scottish border extending from Liddisdale westwards towards Annandale, the operations in the field being carried on by Mr R. Logan Jack, Mr Skae, and Mr Wilson.

* *Memoirs of the Lit. and Phil. Soc. of Manchester*, third series, vol. ii. p. 343: also an abstract of same paper, *Proc. of the Lit. and Phil. Soc. of Manchester*, vol iii. p. 162.

† "Note on the Upper Coal-measures of Canonbie, Dumfriesshire," by E. W. Binney, F.R.S., *Proc. of the Lit. and Phil. Soc. of Manchester*, vol. xvi. p. 192.

Before the survey of that district was completed Mr Jack, who had mapped the greater portion of the area, left for Queensland, and the completion of the work was shared by Mr B. N. Peach. In the course of the survey great difficulty was experienced in correlating the subdivisions of the Carboniferous system as there developed with those of the Midland valley of Scotland, due partly to the variation in some of the groups from the normal Scottish types, and partly to the fact that the mapping of the Carboniferous rocks of the north of England had not been completed to the Scottish border. Eventually, the view was adopted and expressed in the Geological Survey map of the district (sheet 11—one inch) that the Canonbie coalfield belonged to the Calciferous Sandstone series, which represented part of the Carboniferous Limestone series of England.

The palæontological evidence, however, did not harmonise with this conclusion. After the mapping was completed Mr Macconochie began the fossil-collecting in that district, and obtained a series of plants from the Canonbie coalfield and from Carboniferous strata occupying a lower geological horizon. These plants were named and described by Mr Kidston, the results of his researches being published in the Transactions of this Society.* In his paper a list of the plants from that coalfield was given, but no geological horizon was assigned to them, out of deference to the view then held by the Geological Survey. On the evidence of the plants alone, he was led to the same conclusion as that of Mr Gibsone and Mr Binney, that the coal-bearing strata of Byre Burn and Rowanburn belong to the Coal-measures. In the course of his work Mr Macconochie incidentally found plants in certain red shales at Jockie's Sike, near Riddings Junction, which suggested to Mr Kidston that these red shales and sandstones near the border might be the representatives of the Upper Coal-measures of England. This striking confirmation of Mr Binney's sagacious conclusion regarding the age of these sandstones was first announced by Mr Kidston in his presidential address to the Royal Physical Society, Edinburgh, in 1893.

It may be further noted that Mr Macconochie, while collecting the fossils from the massive limestones of Peterscrook, Harelaw Hill, and Gilnockie, was struck with the resemblance of the facies of organic remains to that found in the lower limestones of the Edge Coal series of the Midland valley of Scotland. This opinion was shared by the late Mr Bennie, who compared the microzoa from the shales of the Gilnockie limestone with those obtained from the horizon of the Hurlet limestone of Fife.

The subsequent completion of the mapping of the Carboniferous rocks in Northumberland, northwards to Berwick and the Cheviots, threw much light on the sequence and peculiar lithological features of the members of that system in Liddisdale and Eskdale.

The revision of the Scottish coalfields, now in progress, furnished an opportunity

* "Report on Fossil Plants collected by the Geological Survey of Scotland in Eskdale and Liddisdale," *Trans. Roy. Soc. Edin.*, vol. xxx. p. 531.

last year of re-examining certain typical sections in Liddisdale, Eskdale, and westwards towards the Annan valley. A large collection of plants was obtained by Mr KIDSTON and Mr MACCONOCHIE, which are described by Mr KIDSTON in his paper now presented to the Society* on "The Fossil Plants of the Carboniferous Rocks of Canonbie, Dumfriesshire, and of Parts of Cumberland and Northumberland." On the evidence of the plants he correlates the Rowanburn coal-bearing group with the Lower Coal-measures, the Byre Burn group with the Middle Coal-measures, and the red sandstones and shales in the Liddel between Penton and Riddings Junction and in the Esk north of Canonbie bridge with the Upper Coal-measures of England.

Important information has been supplied by two deep bores sunk in recent years through the red sandstones and shales (Upper Coal-measures) near Canonbie. By the courtesy of His Grace the Duke of Buccleuch, we have been furnished with copies of the journals of these bores, and have received his permission to publish them. We likewise obtained leave to examine the cores of these deep bores, now stored at the Rowanburn Colliery; and in the course of our work we have been supplied with much information by the mining managers. For such valuable aid, so generously rendered, we desire to express our cordial thanks.

In the sequel, we propose to describe in turn the various subdivisions of the Carboniferous system in the tract extending from Liddisdale to Annandale, illustrating the geological structure of the region by a series of horizontal sections. Thereafter it will be shown by means of comparative vertical sections that the Lower Carboniferous sequence of the Scottish border closely resembles that of Northumberland, and differs in important points from that of Central Scotland.

## II. DESCRIPTION OF THE CARBONIFEROUS SUBDIVISIONS IN ESKDALE AND LIDDISDALE.

The order of succession of the strata and the lithological characters of the various subdivisions of the Carboniferous system of the Scottish border is presented in the subjoined table :—

* *Trans. Roy. Soc. Edin*, vol. xl. pp. 741-833.

TABLE OF THE CARBONIFEROUS SYSTEM IN ESKDALE AND LIDDISDALE.

| | | |
|---|---|---|
| Trias | | Brick-red sandstones and marls. |
| | | Unconformability. |
| Upper Carboniferous | Upper Coal Measures | Red Sandstones and Shales: stained in part.—With plants of Upper Coal-measures. |
| | Middle Coal Measures | Byre Burn Coal group.—Sandstones, shales, coals, and thin ironstones; stained in part.—With plants of Middle Coal-measures. |
| | Lower Coal Measures | Rowanburn Coal group.—Several workable coals; sandstones, shales, and ironstones.—With plants of Lower Coal-measures. |
| Lower Carboniferous | Millstone Grit | Coarse sandstones, shales, and several thin coals; proved in bores. |
| | Up. Ls. Group | Marine limestones, sandstones, and shales. About 240 feet thick. |
| | Coal-bearing Group | A group of five thin coals—Kilnholm coals (Horizon of Lickar and Edge coals)—sandstones and shales. Upwards of 340 feet thick. |
| | Low. Ls. Group | Group of marine limestones, sandstones, shales, and thin coals. |
| | Lawston Linn and Muir Burn Coal Group | Sandstones, shales, marine limestones, thin coals, and ironstones.—Horizon of Lewisburn and Plashetts (Scremerston coals). |
| | Glencartholm Volcanic Group | Basic tuffs and lavas (Olivine-basalts), with interbedded shales and mudstones. |
| | Fell Sandstones | Grey and yellow sandstones, with red marls and thin impure limestones. |
| | Cementstone Group | Cementstones and impure limestones, clays, sandstones, and a zone of marine limestone near the top—(Larriston and Thorlieshope limestones). |
| | Whita Sandstone | Grey and yellow sandstones. |
| | Birrenswark Volcanic Group | Lavas (Olivine-basalts). |
| Old Red Sandstone | Upper Old Red Sandstone | Red sandstones and shales, with cornstone and chert at top. |
| | | Unconformability. |
| Silurian | | Silurian strata. |

Before proceeding to the description of the subdivisions of the Carboniferous system, brief allusion may be made to the succession of red sandstones which, though they pass conformably upwards into that system, are grouped with the Old Red Sandstone, in virtue of their fish fauna.

### *Upper Old Red Sandstone.*

Along the southern flanks of the Silurian tableland the members of this system rest unconformably on the folded and denuded edges of the Upper Silurian rocks. Owing to the uneven floor on which they were deposited, their thickness varies in every section where they are exposed. Near Langholm it is about 300 feet, and yet about three miles to the west of that town these rocks almost wholly disappear. Near the base the

strata consists of reddish pebbly sandstones, composed mainly of materials derived from the Silurian tableland, but at certain localities, as for instance on the west slope of Whita Hill, there is an admixture of debris of igneous rocks resembling the Lower Old Red Sandstone andesites of the Cheviots. These are overlaid by red carious weathering sandstones, with occasional pebbles; and towards the top the calcareous matter is aggregated in knots and lenticles, evidently representing the horizon of the cornstone which occurs near the top of this formation. Indeed, near Riccarton, in the north-west, this zone does occur, where it is often accompanied by a lenticular red chert band. No fish-remains have been found in these strata near Langholm, but in the sandstones of Dinley Burn, near the Dinley Spout, a tributary of the Hermitage Water, scales of *Holoptychius nobilissimus* have been met with.

### *Lower Carboniferous Rocks.*

#### i. *The Volcanic Rocks of the Tarras Water and Birrenswark.*

In the district now under consideration the Upper Old Red Sandstone strata are everywhere surmounted by a zone of contemporaneous volcanic rocks that form a well marked horizon in the geological sequence. The lava flows, which are usually slaggy and much decomposed, are of a basic character, ranging from olivine-basalts to andesitic basalts. Hardly any tuff or volcanic agglomerate has been observed in this volcanic zone. As might naturally be expected, few vents filled with volcanic agglomerate pierce the strata of a lower geological horizon to the north of the volcanic platform. But in the area north of the Tarras and Ewes Waters (sheet 17—one-inch) numerous plugs or stocks of intrusive igneous rocks, of intermediate or acid types, resembling those of the Eildons near Melrose, appear within the Silurian area. An excellent example of a plug of andesitic basalt rising through the Upper Old Red Sandstone underlying the volcanic zone is to be found on Arkleton Hill, six miles north of Langholm, in the basin of the Ewes Water.

This volcanic zone forms a narrow fringe round the Carboniferous area, though the outcrop is much interrupted by faults, some of which are of considerable magnitude. It has been traced for several miles along the eastern margin of the Silurian inlier near Riccarton. From Dinley on the Hermitage Water, it has been followed at intervals across the heights to the Whita Hill near Langholm, thence westwards by Waterbeck and Middlebie to Birrenswark, and beyond the Dumfries basin of the New Red Sandstone it reappears in the district of Kirkbean.

#### ii. *The Whita Sandstone.*

The volcanic zone of Birrenswark and the Tarras Water is overlaid by a group of sandstones which are characteristically developed on the Whita Hill, about half a mile

east of Langholm. At the base, the beds consist of pink pebbly sandstones, the pebbles being well rounded and composed of vein quartz. These pass upwards into yellowish or grey mottled gritty sandstones, with marked false-bedding, and containing clay galls and specks of decomposing carbonates. Near the base of this type, and above the pinkish sandstone, there are occasional lenticular beds of ochreous cementstone. The highest members of the group consist usually of coarse, mottled, carious weathering sandstones, with decomposed, rusty carbonates. Occasionally beds of greenish shale and cementstone are intercalated in the series near the top. It is highly probable that the galls of shale and particles of carbonate found in the sandstone have been derived from the erosion of the beds of shale and cementstone that appear to have been laid down during pauses in the deposition of coarser sediment. The thickness of this zone ranges from 600 to 700 feet.

In the Esk south of Langholm, from Longwood to below Broomholm—a distance of about a mile—this arenaceous group may be traced in natural sequence above the volcanic zone of the Tarras Water and Birrenswark. Thence they stretch northwards, forming the tops of the Fells from the Whita Hill to Dinley Fell near the Hermitage Water—a distance of nearly twelve miles. Across the Hermitage Water they may be followed north-eastwards as far as the Whitterhope Edge, where they are truncated by a fault. A second outcrop of this group of sandstones appears in the upper part of the valley of the Liddel and to the east of the Silurian inlier at Riccarton. From Liddel Castle, about three miles above New Castleton, it extends north-eastwards, flanking the rocks of the Birrenswark volcanic zone, across the Riccarton, the Dawston, and the Caddroun Burns, beyond which the sandstones are obliquely truncated by a fault. Along this outcrop the Whita sandstones cannot exceed 300 feet in thickness, and they appear to thin out towards the north-east.

### iii. *Cementstone Group.*

This subdivision consists mainly of green, blue, and grey mudstones and sandy shales, with bands of impure muddy limestone and cementstone, with occasional intercalations of coarse grey calcareous sandstone. Near the top there is a zone of true marine limestone. In the Langholm district the thickness of this group varies from 1200 to 1500 feet.

The cementstone group of Eskdale and Liddisdale was evidently deposited along shore under estuarine conditions, the mudflats being suitable for the growth of lamellibranchs, which occur in profusion in certain beds. Indeed, in some bands one species of *Modiola* appears, to the exclusion of every other form. The characteristic shell is *Modiola Macadami* and its varieties, but other bivalves also occur, though less abundantly. A good section of these beds exposed in the cliff of the Liddel Water opposite

the manse, about two miles above New Castleton, yielded the following assemblage of lamellibranchs, with which *Spirorbis* is usually associated :—

*Spirorbis*, sp.
*Anthracomya subparallela.*
*Ariculopecten Geikici*, Eth. jnr. M.S.
*Edmondia josepha*, De Kon.
*Leiopteria*, sp.
*Modiola Macadami*, Portl.
*Myalina sublamellosa*, Eth. jnr.
„ *Verneuili*, M'Coy.
*Naiadites*, sp.
*Nuculana attenuata*, Flem.
„ *stilla*, M'Coy.
*Protoschizodus axiniformis*, Portl.
„ *nuculoides*, M'Coy.
„ sp.
*Sanguinolites roxburgensc*, Hind.
*Schizodus*, sp.
*Tellinomorpha cunciformis*, De Kon.

The forms given in the foregoing list are often associated with remains of the higher crustacea of the genera *Palæocrangon*, *Anthrapalæmon*, and *Pseudogalathea*, while entomostraca are frequently abundant. Among the Xiphosura, *Prestwichia* and *Cyclus* occur. Occasionally there is evidence of purer marine conditions, indicating incursions of the sea, as we may gather from the presence of *Lingula squamiformis*, *Discina nitida*, and more commonly *Camarophoria crumena*. Some of the beds of thin limestone in this group are composed mainly of the remains of the last of these forms in association with *Athyris ambigua* and *Orthotetes crenistria*. Such marked proofs of more marine conditions are rare in the lower part of the Cementstone group, embracing about 500 feet of strata ; but above that level they are more numerous. Indeed, from the thickness of the marine limestones which have been worked in the upper part of Liddisdale, in the valley of Larriston Burn, Thorlieshope, and near Dead Water, on this horizon, it is clear that marine conditions must have lasted for considerable intervals of time. This zone is characterised by a form of *Syringothyris* (*Spirifera*) *cuspidata*, which, with one exception, has been found in this area only in this zone. The exception referred to occurs on a slightly higher horizon than the Larriston Burn limestone.

A list of fossils is subjoined from the limestones of Thorlieshope and Larriston Burn, which is sufficient to demonstrate that marine conditions prevailed during their deposition. At the same time it may be observed that many forms which appear in the marine limestones overlying the Fell sandstones are absent from this list. The abundance of lamellibranchs and gasteropods in this marine zone below the Fell sandstones seems to imply that a considerable amount of sediment was then present in the sea-water.

List of fossils from the marine limestones of Thorlieshope and Larriston Burn :—

*Chætetes tumidus*, Phill.
*Palæacis cyclostoma*, Phill.
*Syringopora ramulosa*, Goldf.
*Lithostrotion junceum*, Flem.
*Palæchinus globulus.*
*Poteriocrinus crassus*, Miller.
*Spirorbis ambiguus*, Flem.
*Entomostraca.*
*Athyris ambigua*, Sow.
„ *Roysii*, Lév.
*Camarophoria crumena*, Mart.
*Lingula scotica*, Dav.
*Productus longispinus*, Sow.
„ *semircticulatus*, Mart.
*Rhynchonella*, sp.
*Spirifera bisulcata*, Sow.
„ *trigonalis*, Mart.
*Syringothyris* (*Spirifera*) *cuspidata.*
*Allorisma sulcata*, Flem.
*Aviculopecten cælatus*, M'Coy.

*Aviculopecten interstitialis*, Phill.
„ *macrotis*, M'Coy.
*Modiola Macadami*, Portl.
„ sp.
*Myalina sublamellosa*, Eth. jnr.
*Nuculana attenuata*, Flem.
*Nucula stilla*, M'Coy.
*Protoschizodus axiniformis*, Portl.
*Sanguinolites costellatus*, M'Coy.
„ *striato-lamellosus*, De Kon.
„ sp.
*Tellinomorpha cuneiformis*, De Kon.
*Edmondia josepha*, De Kon.
*Edmondia pectunculus*.
*Entolium Sowerbyi*, M'Coy.
*Loxonema curvilinea*, Phill.
„ sp.
*Murchisonia Verneuliana*, De Kon.
*Macrochcilus acutus*, Sow.
*Naticopsis plicistria*, Phill.
*Ivania* (*Pleurotomaria*) *Ivani*, Lév.
*Conularia quadrisulcata*, Sow.
*Discitoceras* (*Discites*) *sulcatus*, Sow.
*Orthoceras attenuatum*, Flem.
„ *lineale*, De Kon.
„ sp.

Above the horizon of the marine limestones of Thorlieshope the strata indicate a reversion to estuarine conditions. Immediately below the Fell sandstones, however, a well marked and persistent band of limestone appears, charged with a peculiar calcareous organism, named *Mitcheldeania gregaria* by the late Professor Alleyne Nicholson. It occurs in the well known limestone at Kershopefoot and at Kidds Linn.

Though land plants occur more or less frequently throughout the group, it is only occasionally that a true land surface is indicated by an under-clay with underground rhizomes such as *Stigmaria* in place. One thin coal-seam, however, about ten inches thick, is found near the top of the Cementstone group, under Peel Fell on the Scottish side, which is the lowest known coal-seam on the border. The characteristic ferns of the group are *Calymmatotheca* (*Sphenopteris*) *affinis* and *C. bifida*; at Tarrasfoot *Rachopteris inæquilatera* also occurs.

The fishes found in the Cementstone group are not of common occurrence, and, as might be expected, are almost wholly of an estuarine character. These have been submitted to Dr Traquair for determination, who has identified the following forms in the collection: *Strepsodus*, sp., *Rhadinichthys Macconochiei*, Traq., and *Styracopterus fulcratus*, Traq. In the marine limestone zone of Thorlieshope and Larriston Burn palatal teeth of marine sharks have been obtained.

Land animals also occur in the form of Scorpions, while Myriapods belonging to more than one genus have been found in rocks of this horizon in the basin of the Tweed near Coldstream.

From the peculiar lithological characters of the Cementstone group, the distribution of the beds is comparatively clear in Eskdale and Liddisdale. In the Esk and in the lower part of the basin of the Tarras Water they form a simple outcrop overlying the Whita sandstone, and dipping generally in a southerly direction at an average angle of about 20°. When followed north-eastwards to the Tinnis Burn they are spread over a wide area, owing to repetition by folding, and occupy a basin three miles in width, which extends up the Hermitage Water towards the northern margin of sheet 11 of the one-inch map of Scotland. On its eastern side this basin is truncated by a powerful north and south fault which brings the Cementstone group successively in contact with the Upper Silurian inlier of Arnton Fell near Riccarton, and with the Upper Old Red

sandstone and Birrenswark volcanic zone near the junction of the Liddel and Hermitage Water. (See Plate III. section 1.)

In Upper Liddisdale, to the east of the Silurian inlier just referred to, near Riccarton, the Cementstone group is again repeated, resting in natural sequence on the Whita sandstone and Birrenswark volcanic zone, and dipping towards the south-east. In that district they floor the course of the Liddel Water, and form the lower slopes of the Larriston Fells. Owing to minute folding of the beds it is difficult to give an accurate estimate of their thickness, but it is probably about 1200 feet. The Larriston Burn furnishes a good section, especially of the marine limestone zone, near the top.

### iv. *The Fell Sandstones.*

The Cementstone group of Liddisdale and Eskdale is overlaid by a succession of sandstones, with intercalations of red and green marly clays, and occasional impure cementstone bands, varying in thickness from 400 to 600 feet. The sandstones are siliceous and usually fine-grained, but sometimes become coarse and pebbly. At certain localities they contain marine fossils such as *Aviculopecten*, while the impure limestone bands contain cyprids and modioliform shells, but there is no indication of clear water conditions.

In the district of Peel Fell there is evidence of successive land surfaces in the form of dirt beds, and even of thin coal-seams, which accompany the red and green marls and impure fireclays separating the beds of sandstone.

From a stratigraphical point of view this group of sandstones is of great importance, inasmuch as the zone is persistent and easily traceable. They form much of the higher part of the Larriston Fells, where they lie in a synclinal fold, overlaid by the upper volcanic zone at the base of the Lewisburn coal-bearing beds (Scremerston position), to which reference will be made in the sequel. (See Plate III. section 1.) When traced towards the south-west, owing to the fall in the ground, the Fell sandstones appear in the centre of the trough, but on Caerby Hill they are capped by the upper volcanic zone. Crossing the Liddel at Kershopefoot, they extend westwards along the slopes south of the Tinnis Burn, and form the high ground separating that stream from the Tarras Water. They are visible in the Esk at Irvine House, and towards the south-west they are traceable across the moorland to the south of Ecclefechan, where they form the prominent eminences of Brown Moor and Woodcock Air, on either side of the Annan. West of the Nith this zone appears on the shore between Arbigland and Southerness Point.

### v. *Glencartholm Volcanic Group.*

Next in order above the Fell sandstones comes the volcanic group of Glencartholm, which, though of no great thickness, has been of service in working out the stratigraphical arrangement of the beds between the Esk and the Liddel. In the Esk section

the group consists of fine decomposing basic tuffs and thin basic lava, in the midst of which there is a zone of sediments, comprising black shales, oil shale, and black cherts, followed by fine-grained calcareous shale of unique palæontological importance. From this horizon of calcareous shale a great variety of organic remains has been obtained, including plants, ostracods, brachiopods, lamellibranchs, cephalopods, crustaceans, fishes and land animals (scorpions and eurypterids). The extraordinary feature of the band is the very large number of new genera and species gathered from this single exposure in the Esk, which has made it one of the classic fossil-localities in Scotland. The discovery was made by the skilled fossil-collector of the Geological Survey, Mr A. Macconochie. From the fact that these sediments are both underlaid and overlaid by tuff, it is evident that they are merely an episode in the phase of volcanic activity on this horizon. Indeed, it is worthy of note that this rich palæontological zone, though carefully sought for, has not been found at any other locality.

Though a great variety of forms has been obtained from the Glencartholm shales, it is interesting to observe that they are not equally distributed through the successive layers. For example, the fishes are usually found underneath a band in which *Orthoceras* is a conspicuous fossil. The scorpions and plants usually occur together in a separate bed, while the crustaceans are found in association with the fishes. The ferns are usually represented by separate fronds, and they are often covered with a calcareous incrustation, as if they had floated about in concentrated calcareous solutions before becoming embedded. No coal-seam nor root-bed appears in this zone. The remains of the crustacea seem to have been filled in with orbicular calcite during decomposition, as if they had lain in water highly charged with calcium sulphate. This feature seems to point to lagoon conditions, as if arms of the sea had been temporarily cut off from the open ocean and subjected to desiccation. Strings of *Spirorbis* and of an adherent brachiopod shell are often found, fixed to carbonaceous stems of decomposing plants. Some of the bands of shale are covered with the chitinous tubes of marine worms. Sea-weeds are represented by *Bythotrephis*.

In view of the evidence regarding the conditions of entombment of the organic remains, it is highly probable that the Glencartholm shales may have been deposited in a muddy creek, shut off at intervals from the open ocean.

In his recent valuable paper "On the Distribution of Fossil Fish-remains in the Carboniferous Rocks of the Edinburgh District,* Dr Traquair states that out of the large number of fishes found at Glencartholm, only one (*Tristychius minor*) is found in the Lower Carboniferous rocks of central Scotland. But it is quite possible, when the divisions of the Lower Carboniferous rocks in Berwickshire, the Lothians, Fife, and the West of Scotland have been thoroughly searched, some forms, now restricted to Glencartholm, may be found. The present revision of the coalfields furnishes an opportunity of testing this question. In connection with this point it may be observed that some of the crustaceans which were at first thought by Dr Peach

* *Trans. Roy. Soc. Edin.*, vol. xl. p. 687.

to be peculiar to the Glencartholm shales, have since been proved to possess a wide distribution. Some have been found in the Cementstone group in the Whiteadder and Blackadder sections in Berwickshire and at Belhaven Bay in Haddingtonshire, and some on still higher horizons in the Granton sandstone at Craigleith, and in the Wardie shales on the shores of the Firth of Forth. Indeed, Dr Peach is confident that further search may extend the present known limits of their distribution.

The subjoined list gives the fossils collected from the Glencartholm shales.*

*Bythotrephis acicularis*, Göpp., sp.
„ *plumosa*, Kidston, sp.
„ *simplex*, Kidston, sp.
„ *Scotica*, Kidston.
*Calymmatotheca bifida*, L. and H., sp.
*Sphenopteris crassa*, L. and H.
„ *pachyrrhachis*, Göpp.
„ *obovata*, L. and H.
„ *Hibberti*, L. and H., *var.*
„ *decomposita*, Kidston.
„ *Maeconochiei*, Kidston.
*Rhodea Machancki*, Ett., sp.
*Rhacopteris inæquilatera*, Göpp., sp.
„ *Geikiei*, Kidston, sp.
*Cardiopteris polymorpha*, Göpp., sp.
*Eskdalia minuta*, Kidston, sp.
*Asterocalamites serobiculatus*, Schl., sp. } = *Pothocites Grantoni*, Paterson. }
*Volkmannia*, sp.
*Lepidodendron Veltheimi*, Sternb.
*Lepidophyllum lanceolatum*, L. and H.
*Lepidostrobus variabilis*, L. and H.
„ *fimbriatus*, Kidston.
*Carpolithes*, sp.
*Ptilophyton plumula*, Dawson, sp.
*Beyrichia gigantea*, Jones.
*Acanthocaris elongatus*, Peach.
„ *attennatus*, Peach.
„ „ *scorpioides*, Peach.
*Anthrapalæmon Etheridgei*, Peach.
„ „ var. *latus*, Peach.
„ *formosus*, Peach.
*Pseudogalathea Maeconochici*, Eth. jnr., sp.
*Rostrocaris falcatus*, Peach.
„ *Traquairi*, Peach.
*Palæosquilla Parki*, Peach.
„ sp.
*Palæocaris scoticus*, Peach.
*Palæocarangon elegans*, Peach.
„ *eskdalensis*, Peach.
*Eoscorpius euglyptus*, Peach.
„ *glaber*, Peach.
„ sp.
*Glyptoscorpius*, sp.
*Cyclus testudo*, Peach.
*Prestwichia rotundata*, Peach.
*Discina nitida*, Phill.
*Lingula mytiloides*, Sow.
„ *squamiformis*, Phill.
„ sp.
*Productus semireticulatus*, Martin.
*Small adherent brachiopod.*
*Avicula Hendersoni*, Eth.
*Aviculopecten Geikiei*, Eth., M.S.
„ *eskdalensis*, Hind.
„ *interstitialis*, Phill.
„ *papyracea*, (?) Goldf.
„ *planicostatus*, M'Coy.
„ sp.
*Edmondia josepha*, De Kon.
„ sp.
*Entolium Sowerbyi*, M'Coy.
*Leiopteria divisa*, M'Coy.
*Lithodomus carbonarius*, Hind.
*Modiola Macadami*, Portl.
*Myalina sublamellosa*, Eth. Jnr.
„ sp.
*Pinna mutica*, M'Coy.
*Posidonomya radiata*, Hind.
*Pteronites angustatus*, M'Coy.
*Sanguinolites variabilis*, M'Coy.
*Sedgwickia ovata*, Hind.
*Euomphalus catillus*, Sow.
„ *pentangulatus*, Sow.
*Murchisonia suleata*, M'Coy.
*Naticopsis plicistria*, Phill.
*Conularia quadriseuleata*, Sow.
*Orthoceras*, sp.
*Acanthodes nitidus*, A. S. Woodw.
*Acrolepis ortholepis*, Traq.
*Canobius elegantulus*, Traq.
*Cheirodopsis Geikiei*, Traq.
*Chondrenchelys problematica*, Traq.
*Cladodus*, sp.
*Cœlacanthus Huxleyi*, Traq.
*Cycloptychius concentricus*, Traq.
*Elonichthys pulcherrimus*, Traq.
„ *serratus*, Traq.

* The list of fishes from Glencartholm given by Dr Traquair in his paper already referred to has been embodied in the above list.

*Eurynotus*, two species.
*Mesolepis rhombus*, Traq.
„ *tuberculatus*, Traq.
*Mesopoma politum*, Traq.
„ *pulchellum*, Traq.
„ *Ramsayi*, Traq.
*Phanerosteon mirabile*, Traq.
*Platysomus superbus*, Traq.
*Rhadinichthys angustulus*, Traq.
*Rhadinichthys delicatulus*, Traq.
„ *fusiformis*, Traq.
„ *Maceonochiei*, Traq.
„ *tuberculatus*, Traq.
*Sphenacanthus costellatus*, Traq.
*Strepsodus*, two species.
*Tarrasius problematicus*, Traq.
*Tristychius minor*, Portl.

The tuffs of the Glencartholm volcanic group have been traced for five miles towards the E.N.E. to the head of Muir Burn that joins the Liddel Water at Liddel Bank, but the richly fossiliferous shales have not been found in association with them. Chert beds, however, accompany the tuffs and basaltic lavas in Muir Burn. The small outlier of basic lava that caps the hill near Dinwoodie, east of Muir Burn, is probably on this horizon. East of the Liddel we encounter this volcanic zone in the Kershope Burn, about half a mile above its junction with that stream, whence its outcrop sweeps northwards by the top of Caerby Hill, and curves eastwards till it recrosses the Kershope Burn and passes into Cumberland, about a mile and a half north-east of Kershopefoot Station. Owing to the synclinal arrangement of the strata in Larriston Fells, the basaltic lava on this horizon forms in that region a narrow outcrop, encircling sediments at the base of the overlying Lewis Burn coal-bearing group.

West of the Esk, this volcanic zone can be traced up the south bank of the Irvine Burn, and still further to the west it appears in the Palling Burn—a tributary of the Water of Sark—about four miles W.S.W. of Glencartholm.

### vi. *Marine Limestone Series with Coal-seams.*

In Eskdale and Liddisdale the Glencartholm volcanic zone is followed in natural sequence by sediments in which marine limestones are a prominent feature with thin coal-seams on two horizons which have been worked at certain localities. The members of this series may be classified as follows :—

| | Thickness. |
|---|---|
| 4. Upper Limestone group . . . . . | 300–400 feet |
| 3. Kilnholm Coal group (horizon of Lickar coals) . . | 342 „ |
| 2. Lower Limestone group . . . . . | 500–700 „ |
| 1. Lawston Linn and Lewis Burn Coal group (horizon of Scremerston coals) . . . . . | 400–500 „ |

1. *The Lawston and Lewis Burn Coal Group.*—In Eskdale and Liddisdale the members of this subdivision consist of sandstones, shales, thin coals, and thin marine limestones. At Lawston Linn, on the Liddel, a coal from one foot six inches to two feet thick was formerly extensively wrought on this horizon, which is the most prominent seam. Other coals of less thickness, together with an oil shale, also occur at that locality. Again, at Muir Burn, near the head of Archer Beck, similar thin coals appear in this position. In the Esk section thin coals almost immediately succeed the

Glencartholm volcanic tuff, occupying the same relative position as the Lawston seams, but too thin to be of any economic value. They are visible also in tributaries of the Esk, on both sides of Glencartholm, where, as in the Esk, they frequently have limestone roofs.

A limestone, from six to eight feet thick, almost immediately overlies the coal formerly wrought at Lawston Linn, which, from the fossils given in the annexed list, is of undoubted marine origin :—

*Clisiophyllum*, sp.
*Lithostrotion cæspitosum*, Mart.
*Athyris ambigua*, Sow.
*Productus giganteus*, Mart.
„ *punctatus*, Mart.
*Spirifera trigonalis* var. *bisulcata*, Mart.

Calcareous nodules in soft shales from the same locality yielded the following assemblage of organic remains, which indicate less purely marine conditions.

*Clisiophyllum*, sp.
*Lithostrotion irregulare*, Phill.
*Arehæocidaris Urei*, Flem.
*Fenestella*, sp.
*Athyris ambigua*, Sow.
„ *Roysii*, Lév.
*Camarophoria crumena*, Mart.
*Productus punctatus*, Mart.
*Spirifera lineata*, Mart.
*Syringothyris* (*Spirifera*) *cuspidata*, Mart.
*Allorisma sulcata*, Flem.
*Aviculopecten cælatus*, M'Coy.
„ *Geikiei*, Eth. M.S.
„ *interstitialis*, Phill.
*Edmondia sulcata*, Phill.
*Nueulana attenuata*, Flem.
*Pteronites angustatus*, M'Coy.
*Sanguinolites roxburgensis*, Hind.
„ *variabilis*, M'Coy.

Similar fossil-lists might be supplied from the limestones on this horizon in Archer Beck and in the Esk.

In the Kershope Burn, not far up stream from Kershopefoot, the lowest beds of this group rest on the Glencartholm volcanic zone, where two coal-seams were formerly wrought on the English side of the border. Again, in the upper part of Tweeden Burn and its tributaries, south-east of New Castleton, there are sections showing outcrops of coal-seams, some of which seem to have been formerly wrought, in association with sediments that overlie the upper volcanic zone so well seen on the Fell top, near Tweedenhead. These strata are evidently the continuation of those forming the Lewis Burn Coal group just across the border. The limestones on this horizon in the Tweeden Burn do not indicate such clear water-conditions as those of the Liddel, Muir Burn, or Archerbeck, as shown by the fossils in the subjoined list.

*Lingula mytiloides*, Sow.
„ *squamiformis*, Phill.
*Camaraphoria erumena*, Mart.
*Productus cora*, d'Orb.
*Aviculopecten cælatus*, M'Coy.
„ *dissimilis*, Phill.
„ *planicostatus*, M'Coy.
„ *segregatus*, M'Coy.
„ sp.
*Edmondia unioniformis*, Phill.
*Entolium Sowerbyi*, M'Coy.
*Leiopteria*, sp.
*Naiadites* (*Myalina*) *crassa*, Flem.
*Nueulana attenuata*, Flem.
*Protoschizodus axiniformis*, Portl.
*Sedgwickia ovata*, Hind.
*Bellerophon hiuleus*, Sow.
„ *decussatus*, Flem.
„ „ var. *striatus*, Flem.
*Euomphalus Dionysii*, Goldf.
*Loxonema constrictum*, Sow.
„ *curvilineum*, Phill.

*Narica variata*, Phill.
*Naticopsis plicistria*, Phill.
*Ivania* (*Pleurotomaria*) *Ivani*, Lév.
*Trochus hisingerianus*.
*Conularia quadrisulcata*, Sow.
*Orthoceras*, sp.
*Archichthys Portlocki*, Ag.
*Cœlacanthus lepturus*, Ag.
*Eurynotus aprion*, Traq.
„ *crenatus*, Ag.
*Megalichthys*, sp.
*Strepsodus sauroides*, Ag. M.S.
*Wardichthys cyclosoma*, Traq.

2. *The Lower Limestone Group.*—As developed in Eskdale and Liddisdale, this subdivision differs in one important aspect from that just described. While the group as a whole consists of a constant alternation of sandstones, shales, fireclays, thin coals, and limestones, its distinctive feature is the massive nature of some of the limestones and their true marine character. The latter are admirably seen in the Liddel Water at Penton Linns, at Harclaw Hill quarry, and in the Esk above Gilnockie bridge. The following sequence is visible in the lower quarry of Harelaw Hill.

8. Thin black shale.
7. Grey solid limestone, 4 feet.
6. Black shales with ironstone nodules, 15–20 feet.
5. Grey solid limestone, 20–22 feet.
4. Fossiliferous black shales, 1 foot 6 inches.
3. Grey limestone, 3½ feet.
2. Black shale.
1. Coal, 1 foot.

The fossils given in the annexed list which indicate true marine conditions have been obtained from the limestone in Harelaw Hill quarry.

*Lithostrotion junceum*, Flem.
*Hydreionocrinus globularis*, De Kon.
*Dithyrocaris*, sp.
*Phillipsia seminifera*, Phill.
*Polyzoa*.
*Chonetes laguessiana*, De Kon.
*Productus giganteus*, Mart.
„ *longispinus*, Sow.
„ *semireticulatus*, Mart.
„ sp.
*Spirifera lineata*, Mart.
„ *trigonalis*, Mart.
„ „ var. *bisulcata*, Sow.
*Terebratula hastata*, Sow.
*Aviculopecten celatus*, M'Coy.
„ *Geikiei*, Eth.
*Edmondia sulcata*, Phill.
*Sanguinolites striato-lamellosus*, De Kon.
*Euomphalus carbonarius*, Sow.
*Orthoceras sulcatum*, Flem.

The section exposed in the Esk between Glencartholm and Gilnockie bridge furnishes favourable opportunities for studying the members of this subdivision when the river is low. The strata are affected by numerous small folds and faults, but on the whole there is an ascending sequence, with an inclination to the south or south-east. In that part of the section between Gilnockie Tower and Canonbie Mills the limestones are well displayed in the bed and banks of the river, where they are richly charged with corals, brachiopods, cephalopods, and other organic remains. The subjoined list gives the fossils from the limestone and calcareous shales in the Esk near Gilnockie Tower.

*Chætetes septosus*, Flem.
*Clisiophyllum*, sp.
*Lithostrotion aranea*, M'Coy.
„ *junceum*, Flem.
„ *Portlocki*, M. Edw.
*Zaphrentis Enniskilleni*, Edw. and Haime
„ *Phillipsi*, Edw. and Haime.
*Poteriocrinus crassus*, Miller.
*Crinoid stems*.
*Stenopora Howelli*, Nich.
*Athyris ambigua*, Sow.
„ *Roysii*, Lév.
*Camarophoria crumena*, Mart.
*Chonetes comoides*, Sow.

*Lingula squamiformis*, Phill.
*Orthis Michelini*, Lév.
*Productus complectens*, Eth. jnr.
„ *giganteus*, Mart.
„ *llangollensis*, Dav.
„ *scabriculus*, Mart.
*Spirifera lineata*, Mart.
„ *trigonalis*, var. *bisulcata*, Sow.
*Aviculopecten*, sp.
*Lithodomus carbonarius*.
*Myalina*, sp.
*Nuculana attenuata*, Flem.
*Protoschizodus axiniformis*, Portl.
*Bellerophon Urei*, Flem.
*Naticopsis*, sp.
*Pleurotomaria*, sp.
*Orthoceras*, sp.

Perhaps the finest section in the Border region of the limestone group underlying the Kilnholm coals is that visible in the Liddel Water at Penton Linns, about a mile east of Rowanburn Colliery, where the river flows through a gorge carved out of these strata. Along their southern margin the sandstones and shales of the Lower Marine limestone group are truncated by a fault which brings down the red sandstones and shales of the Upper Coal-measures (see Plate III. section 3). North of this fault the members of the marine limestone group have, for a distance of 300 yards, a general dip to the E.S.E. at a moderate angle, where the fossiliferous character of the shales and limestones is admirably seen. Here the limestones are traversed by an east and west fault, with a downthrow to the south, repeating the beds. North of this second fault towards the Penton bridge, the massive limestones of this group are thrown into a well marked anticline, the axis of which appears about a hundred yards west of the latter locality. On the west side of the arch the strata are inclined at high angles, and the successive beds of limestone can there be studied to advantage. From the limestones and calcareous shales at Penton Linns the fossils given in the annexed list have been collected.

*Saccammina Carteri*, Brady.
*Clisiophyllum turbinatum*, M'Coy.
*Lithostrotion irregulare*, Phill.
*Forbesocrinus*, sp.
*Hydrcionocrinus globularis*, De Kon.
*Poteriocrinus crassus*, Miller.
Crinoid stems.
*Phillipsia seminifera*, Phill.
*Diastopora megastoma*, M'Coy.
*Fenestella*, sp.
*Chonetes buchiana*, De Kon,
„ *laguessiana*, De Kon.
*Orthis Michelini*, Lév.
*Productus giganteus*, Mart.
„ *longispinus*, Sow.
„ *semircticulatus*, Mart.
*Rhynchonella pleurodon*, Phill.
*Spinifera trigonalis*, Mart.
„ „ var. *bisulcata*, Sow.
*Ctenodonta pentonensis*, Hind.
*Edmondia pentonensis*, Hind.
*Myalina Verneuili*, M'Coy.
*Nucula brevirostris*, Phill.
„ *gibbosa*, Flem.
*Pinna flabelliformis*, Mart.
*Protoschizodus axiniformis* Portl.
*Sanguinolites variabilis*, M'Coy.
*Streblopteria*, sp.
*Bellerophon decussatus*, Flem.
„ *hiulcus*, Sow.
„ *Urei*, Flem.
*Euomphalus carbonarius*, Sow.
*Loxonema rugifera*, Phill.
„ *scalaroidea*, Phill.
*Macrocheilus*, sp.
*Murchisonia angulata*, Phill.
*Naticopsis lirata*, Phill.
*Pleurotomaria canaliculata*, M'Coy.
*Orthoceras cinctum*, Sow.
„ sp.

The fossils obtained from the limestones and shales of this group at Penton Linns in the Liddel, near Gilnockie Tower on the Esk, and at Harelaw Hill quarry, prove beyond doubt that truly marine conditions prevailed during their deposition; and further, they

recall the assemblage of organic remains so characteristic of the Lower Limestone group of the Edge Coal series (Hurlet and Hosies) of central Scotland.

The massive character of the limestones towards the top of the Lower Limestone group has been proved in the Catsbit bore (see sketch map, Plate I.), sunk close to the farmhouse of Catsbit, about three-quarters of a mile E.N.E. of Rowanburn Colliery, where seventy-five feet of limestone with few intercalations of sediment were pierced beneath the Kilnholm coals. A copy of the journal of this bore is given below.

### Section of Strata in Bore (by Diamond Drill Process) at Catsbit, commenced December 1891.

| Description of strata: | Fms. | Ft. | Ins. |
|---|---|---|---|
| Surface soil | 0 | 2 | 0 |
| Soft red clay | 2 | 0 | 0 |
| Boulders and clay | 4 | 3 | 10 |
| Yellow sandstone | 2 | 2 | 6 |
| Yellow sandstone with coal strains | 0 | 1 | 6 |
| White sandstone | 0 | 1 | 6 |
| White sandstone | 0 | 1 | 11 |
| White sandstone with coal strains | 1 | 2 | 0 |
| Yellow sandstone | 1 | 2 | 0 |
| Broken sandstone (cuttry) | 0 | 2 | 3 |
| Space vacant | 0 | 2 | 0 |
| Yellow sandstone | 0 | 5 | 0 |
| **Coal**, soft and loose | 0 | 0 | 4 |
| Fine white sandstone | 0 | 4 | 5 |
| Yellow sandstone | 0 | 5 | 3 |
| Gray fakes | 0 | 1 | 6 |
| Blue blaes | 0 | 3 | 0 |
| Sandstone white | 0 | 5 | 8 |
| Gray fakes | 0 | 2 | 6 |
| Blue blaes | 0 | 1 | 6 |
| Soft blaes and fireclay | 0 | 0 | 6 |
| Blaes and coal | 0 | 0 | 4 |
| **Coal** | 0 | 1 | 11 |
| Gray fakes | 0 | 0 | 6 |
| Hard white sandstone | 0 | 3 | 2 |
| Blue fakes and blaes | 0 | 2 | 0 |
| Blue blaes and balls | 0 | 3 | 2 |
| **Coal** | 0 | 0 | 5 |
| Light fakes | 0 | 0 | 6 |
| Fakes and sandstone | 0 | 2 | 3 |
| Blue blaes | 0 | 2 | 9 |
| Coarse parrot coal | 0 | 1 | 3 |
| Dark blaes | 0 | 1 | 2 |
| **Coal** and sulphur | 0 | 0 | 4 |
| **Coal** | 0 | 0 | 8 |
| Dark gray fakes | 0 | 2 | 0 |
| Light fireclay | 0 | 1 | 2 |
| Light fireclay and ironstone ball | 0 | 4 | 8 |
| Blue fakes | 0 | 2 | 9 |
| Soft blaes | 0 | 0 | 9 |
| Fakes and sandstone | 0 | 1 | 6 |
| White sandstone cuttry | 0 | 4 | 0 |
| Carry forward | 24 | 4 | 5 |

| Description of strata: | Fms. | Ft. | Ins. |
|---|---|---|---|
| Brought forward | 24 | 4 | 5 |
| Dark gray fakes | 0 | 4 | 0 |
| Fakes and blaes | 0 | 5 | 0 |
| White sandstone | 6 | 3 | 8 |
| White sandstone with coal strains | 0 | 2 | 0 |
| Dark gray fakes | 0 | 4 | 0 |
| Fakes and sandstone | 1 | 2 | 0 |
| Dark blaes | 0 | 0 | 6 |
| White sandstone | 0 | 4 | 6 |
| Gray fakes | 0 | 1 | 0 |
| Yellow sandstone | 4 | 1 | 6 |
| Coarse sandstone and coal strains | 0 | 3 | 0 |
| Fakes and blaes | 1 | 2 | 6 |
| Coarse sandstone | 0 | 1 | 9 |
| Inferior **limestone** | 0 | 1 | 4 |
| Gray sandstone | 1 | 0 | 2 |
| Fakes and blaes | 1 | 0 | 0 |
| **Coal** (loose) | 0 | 1 | 0 |
| Sandstone, white | 1 | 3 | 2 |
| Fakes and sandstone | 0 | 2 | 6 |
| Blue blaes | 0 | 5 | 6 |
| Dark fakes | 0 | 5 | 8 |
| **Coal** | 0 | 0 | 7 |
| Sandstone, white | 0 | 3 | 0 |
| Gray fakes | 0 | 4 | 0 |
| Fakes and blaes | 0 | 5 | 0 |
| Gray fakes | 0 | 5 | 6 |
| Fakes and coal strains | 0 | 0 | 4 |
| Gray fakes | 0 | 2 | 6 |
| Sandstone, gray | 1 | 1 | 0 |
| Blue blaes | 0 | 4 | 5 |
| White sandstone | 0 | 5 | 0 |
| Fakes and sandstone | 0 | 3 | 3 |
| Gray sandstone | 0 | 3 | 0 |
| White sandstone | 1 | 2 | 3 |
| Gray sandstone | 1 | 0 | 9 |
| White sandstone | 3 | 3 | 5 |
| **Coal** (soft) | 0 | 0 | 4 |
| Fakes and blaes | 0 | 0 | 8 |
| White sandstone | 3 | 5 | 6 |
| Dark fakes and coal strains | 0 | 0 | 4 |
| Coarse white sandstone | 1 | 3 | 6 |
| Carry forward | 67 | 5 | 6 |

| Description of strata : | Fms. | Ft. | Ins. |
|---|---|---|---|
| Brought forward | 67 | 5 | 6 |
| Soft fakes | 0 | 0 | 2 |
| Coarse sandstone, white | 2 | 3 | 8 |
| Blue blaes and sandstone | 0 | 1 | 0 |
| Coarse sandstone | 0 | 3 | 7 |
| Blaes | 0 | 0 | 2 |
| Coarse sandstone | 0 | 1 | 5 |
| Blaes, blue | 0 | 0 | 2 |
| White sandstone | 0 | 2 | 6 |
| Fakes and sandstone | 0 | 4 | 10 |
| White sandstone | 0 | 0 | 4 |
| Fakes, blue | 0 | 2 | 2 |
| Fakes and blaes | 1 | 0 | 0 |
| Gray fakes | 0 | 1 | 3 |
| Blaes and **limestone** | 0 | 1 | 0 |
| **Limestone** | 0 | 2 | 0 |
| Gray sandstone | 0 | 3 | 9 |
| Limey fakes | 1 | 1 | 2 |
| Blue blaes | 1 | 0 | 0 |
| **Limestone** | 3 | 1 | 6 |
| **Coal** | 0 | 0 | 6 |
| Carry forward | 81 | 0 | 8 |

| Description of strata : | Fms. | Ft. | Ins. |
|---|---|---|---|
| Brought forward | 81 | 0 | 8 |
| Fakey sandstone | 0 | 2 | 10 |
| White sandstone | 2 | 3 | 10 |
| Fakey sandstone | 1 | 2 | 5 |
| Blue fakes | 0 | 3 | 6 |
| Blue blaes | 1 | 0 | 8 |
| Blaes and **limestone** | 0 | 3 | 0 |
| **Limestone** | 0 | 2 | 8 |
| Limey fakes | 1 | 3 | 6 |
| Blue blaes, limey | 0 | 4 | 0 |
| Blue blaes | 1 | 0 | 2 |
| Blue blaes and balls | 0 | 4 | 0 |
| Blue blaes, limestone ribs | 0 | 4 | 8 |
| **Limestone** | 12 | 5 | 9 |
| **Coal** and sandstone | 0 | 0 | 8 |
| Sandstone, white | 0 | 3 | 9 |
| Dark gray fakes | 0 | 5 | 7 |
| Coarse **coal** | 0 | 0 | 7 |
| Light fireclay, soft | 0 | 3 | 0 |
| **Limestone**, brown and gray | 2 | 0 | 0 |
| Total, | 110 | 1 | 3 |

3. *Kilnholm Coal Group.*—Above the marine limestones just described there is a group of thin coals which, though of little economic value, are of considerable importance from a stratigraphical point of view. Their relative position to the underlying marine limestones of Penton Linns is defined in the Liddel section above Penton bridge, where several thin coals are visible in the banks of the stream, one of which was formerly wrought at Kilnholm. There the sandstones, shales, and thin coals, varying from a few inches to a foot or more in thickness, have an easterly dip, and follow in natural sequence the Penton limestones. They are also visible in the railway section on the English side near Penton House.

In the Esk section, between Gilnockie bridge and the foot of Byre Burn, on an anticlinal fold of the strata, thin coal-seams also appear which are probably on this horizon.

The relative position of this group of thin coal-seams to the Lower Coal-measures of Rowanburn has also been proved in the Rowanburnhead bore (see Plate II.), where they occur underneath the upper limestones. On this horizon six seams were passed through in this bore, five of them being less than one foot thick, and the sixth measuring two feet four inches (see journal of bore, p. 855). Again, in the Catsbit bore (see Plate II.) several thin coal-seams were pierced above the massive lower limestones, all of which, with one exception, are of no economic importance.

In the sequel, evidence will be adduced pointing to the conclusion that the Kilnholm coals occupy the position of the Lickar coals of Northumberland, which have been correlated with the Edge coals of the Carboniferous Limestone series of central Scotland. It is evident, therefore, that there is a marked difference in the economic value of this coal-bearing group to the north and south of the Silurian tableland in Scotland.

4. *Upper Limestone Group.*—The members of this subdivision were proved in an important bore sunk at Rowanburnhead, near the northern margin of the Rowanburn Colliery, to which reference has already been made. A glance at the journal of this bore (see p. 855), and at the diagram of vertical sections, Plate II., shows that the bore was begun in the pavement of the Seven Feet Coal, the position of which in the Rowanburn coalfield is well known. Deducting the thickness of sand and boulder clay at the surface, the first limestone was pierced at a depth of one hundred and eleven fathoms below the pavement of the Seven Feet Seam. Altogether three beds of limestone were passed through, measuring respectively one foot two inches, ten feet, and the lowest, with some intercalations of shale, about twenty feet. Underneath the limestones, as already indicated, lie the thin seams of the Kilnholm coals.

Further evidence relating to the position of this limestone group was obtained in a bore in the bottom of the Old Furnace Pit, Rowanburn, which showed that they underlie some thin coals below the Seven Feet Seam.

Owing to the extensive faulting of the Coal-measures in the Canonbie district, the infraposition of this limestone group to the Lower Coal-measures of Rowanburn has not been proved in any stream section. In the Esk, about one hundred and fifty yards up stream from the foot of Byre Burn, a limestone about three feet thick and calcareous shales appear, charged with *Productus*, *Orthoceras*, and other marine fossils, which may represent one of the bands in this group.

## *Upper Carboniferous Rocks.*

Proceeding now to the consideration of the subdivisions of the Upper Carboniferous rocks of Eskdale and Liddisdale, we encounter serious difficulties owing to the absence of any stream sections showing the original order of succession of the various groups. Judging from the evidence visible at the surface, the field-geologist is at a loss to decide the true sequence of the various subdivisions. The area occupied by these rocks in the Canonbie district is so much traversed by important faults, which have obscured the order of superposition, that any attempt to construct a geological map on surface evidence alone would be liable to error. It is not surprising that the Byre Burn Coal group was regarded as lying beneath the Rowanburn coals, nor that the deep bore sunk from the pavement of the Seven Feet Seam was put down with the view of finding the workable coals of Byre Burn below. That attempt proved a failure, though the upper limestones of the underlying Marine Limestone group were passed through in that trial bore. The result of this bore in some measure paved the way for the classification to which Mr Kidston has recently been led by the evidence of the plants, viz., that the Rowanburn coals represent the Lower Coal-measures, the Byre Burn coals the Middle Coal-measures, and the stained red sandstones and shales the Upper Coal-measures.

### vii. *Millstone Grit.*

Between the workable coal-seams of the Rowanburn group and the upper limestones of the Marine Limestone series, as proved in the Rowanburnhead bore, there is a succession of sandstones, shales, fireclays, and thin coal-seams, about one hundred and eleven fathoms in thickness, which may represent, in part at least, the arenaceous group (Millstone Grit) that intervenes between the Coal-measures above and the Marine Limestone series below. Some of the bands of sandstone revealed in this bore are from eighteen to thirty feet thick. During our recent examination of the district we had an opportunity, through the courtesy of the manager, Mr Bowie, of studying the cores of this bore, and paid special attention to these massive sandstones, some of which are coarse, false-bedded, and pebbly. No plants have been collected from this horizon; and so far as this line of evidence is concerned, it is impossible to say where the boundary should be drawn between the upper and lower divisions of the Carboniferous system.

### viii. *Rowanburn Coal Group (Lower Coal-measures).*

This important group of strata contains the coal-seams which have so long been wrought in the Canonbie district. The area uncovered by the stained red sandstones of the Upper Coal-measures is about half a square mile. The strata are not exposed in any stream section, and the information regarding the sequence of the beds and geological structure of the field is based solely on mining plans. The following vertical section supplied by Mr Bonar, present manager of the Canonbie Colliery, gives the sequence of the coal-seams in descending order.

| | Fm. | Ft. | Ins. |
|---|---|---|---|
| 1. Upper coal | 0 | 3 | 4 |
| Strata | 15 | 4 | 11 |
| 2. Main coal | 1 | 0 | 0 |
| Strata | 12 | 5 | 2 |
| 3. Splint or Nine Feet coal | 1 | 3 | 0 |
| Strata | 0 | 4 | 0 |
| 4. Coal (good) | 0 | 1 | 8 |
| Strata | 1 | 3 | 0 |

| | Fms. | Ft. | Ins. |
|---|---|---|---|
| 5. Three Feet coal | 0 | 3 | 6 |
| Strata | 7 | 0 | 0 |
| 6. Five Feet coal | 0 | 5 | 0 |
| Strata | 7 | 0 | 0 |
| 7. Black top coal | 0 | 4 | 9 |
| Strata | 4 | 0 | 0 |
| 8. Seven Feet coal (local name) | 1 | 0 | 0 |

On referring to the geological sketch map of the district (Plate I.), it will be seen that the coal-seams crop out to the west and north, being truncated on the south by a powerful east and west fault that brings down the stained sandstones and shales of the Upper Coal-measures. On their north-eastern side the strata are likewise bounded by a fault which brings them in contact with the members of the Marine Limestone series. The beds dip towards the east and south-east, and from the coal-workings it appears that they curve up against the great bounding fault on the south side of the field at Rowanburn (see Plate III. section 4).

Reference has already been made to the prevalent opinion that the coals of the Byre Burn group underlie the Rowanburn coals, and with the object of testing this conclusion a deep bore was sunk at Rowanburnhead, a copy of the journal of which is given below.

SECTION OF STRATA IN BORE (BY DIAMOND DRILL PROCESS) AT ROWANBURNHEAD, COMMENCED AT SILL OR PAVEMENT OF "SEVEN FEET SEAM," WITH THE OBJECT OF FINDING THE COAL-SEAMS OF BYRE BURN. BORING COMMENCED MARCH 1891.

| Description of strata: | Fms. | Ft. | Ins. |
|---|---|---|---|
| Surface and sand | 1 | 1 | 0 |
| Boulder clay and stones | 9 | 1 | 0 |
| Fireclay (soft) | 3 | 1 | 0 |
| Light fakes | 0 | 1 | 9 |
| Fireclay broken | 0 | 1 | 8 |
| **Coal** (loose) | 0 | 0 | 9 |
| Fireclay | 0 | 0 | 4 |
| Broken sandstone | 0 | 5 | 0 |
| Fakes and blaes | 0 | 1 | 6 |
| **Coal** (soft) | 0 | 1 | 5 |
| Fireclay and blaes | 0 | 2 | 6 |
| Light fakes | 0 | 1 | 6 |
| Fakes and fireclay | 0 | 2 | 0 |
| Blue fakes | 2 | 0 | 0 |
| Blue fakes and blaes | 0 | 2 | 0 |
| Blue blaes | 0 | 2 | 5 |
| **Coal** | 0 | 1 | 4 |
| **Coal** (soft) | 0 | 0 | 3 |
| Fireclay | 0 | 1 | 6 |
| Fireclay and blaes | 0 | 2 | 6 |
| Sandstone | 0 | 2 | 3 |
| Dark blaes | 0 | 1 | 4 |
| **Coal** | 0 | 1 | 3 |
| Dark fakes | 0 | 0 | 2 |
| Gray fakes | 0 | 0 | 7 |
| Blue fakes | 0 | 2 | 9 |
| Sandstone | 0 | 5 | 0 |
| Fakey sandstone | 1 | 4 | 6 |
| Fakes and blaes | 0 | 1 | 6 |
| **Coal** | 0 | 0 | 7 |
| Fireclay | 0 | 2 | 0 |
| Fakes | 0 | 1 | 0 |
| Sandstone | 0 | 1 | 9 |
| Fakey sandstone | 3 | 0 | 0 |
| Fakey fireclay and blaes | 0 | 4 | 0 |
| Soft fireclay and balls | 0 | 4 | 6 |
| Sandstone | 5 | 0 | 0 |
| Sandstone | 0 | 0 | 5 |
| Fakey sandstone | 0 | 1 | 8 |
| Sandstone | 0 | 1 | 7 |
| Blue Fakes | 1 | 2 | 3 |
| Sandstone | 0 | 2 | 5 |
| Fakes and sandstone | 1 | 2 | 0 |
| Sandstone (variegated) | 1 | 5 | 6 |
| Sandstone | 0 | 5 | 0 |
| Carry forward | 41 | 1 | 5 |

| Description of strata: | Fms. | Ft. | Ins. |
|---|---|---|---|
| Brought forward | 41 | 1 | 5 |
| Fakes and sandstone (variegated) | 3 | 0 | 8 |
| Sandstone | 1 | 2 | 6 |
| Blue fakes and blaes | 2 | 1 | 6 |
| Dark fakes | 0 | 1 | 3 |
| Gray fakes | 0 | 3 | 3 |
| Blue fakes and blaes | 1 | 0 | 0 |
| Fireclay and coal | 0 | 0 | 8 |
| Light fakes and fireclay | 0 | 4 | 6 |
| Sandstone | 0 | 2 | 3 |
| Dark fakes | 3 | 2 | 11 |
| Dark fakes and sandstone | 1 | 5 | 0 |
| Blue fakes | 0 | 4 | 2 |
| Sandstone | 0 | 1 | 8 |
| Blue fakes | 0 | 0 | 10 |
| Sandstone | 0 | 0 | 5 |
| Dark blaes | 0 | 1 | 7 |
| **Coal** | 0 | 1 | 5 |
| Dark fireclay and **coal** | 0 | 0 | 7 |
| Brown fireclay | 0 | 0 | 5 |
| **Coal** | 0 | 1 | 8 |
| Dark fireclay and **coal** | 0 | 0 | 4 |
| Light fireclay | 1 | 0 | 0 |
| Dark fireclay and blaes | 0 | 2 | 4 |
| Light fireclay | 0 | 4 | 0 |
| Sandstone | 0 | 3 | 6 |
| Fakes and sandstone | 0 | 2 | 0 |
| Fakey blaes | 0 | 3 | 0 |
| Dark fireclay and **coal** | 0 | 1 | 9 |
| Fireclay | 0 | 1 | 3 |
| Fakes and fireclay | 0 | 1 | 6 |
| Fakes and sandstone | 0 | 2 | 6 |
| Soft blaes and **coal** | 0 | 0 | 9 |
| Sandstone | 2 | 2 | 3 |
| Extra hard sandstone | 0 | 3 | 10 |
| Fakes and blaes | 0 | 3 | 2 |
| Extra hard sandstone | 2 | 5 | 11 |
| Fakey blaes | 0 | 2 | 3 |
| Light fireclay | 0 | 4 | 6 |
| Light fakes and sandstone | 0 | 5 | 0 |
| Hard cuttry sandstone | 1 | 1 | 0 |
| Fakey sandstone | 0 | 2 | 6 |
| Blue blaes | 0 | 2 | 0 |
| Dark blaes and **coal** | 0 | 0 | 10 |
| Fakes and fireclay | 0 | 1 | 4 |
| Carry forward | 74 | 0 | 2 |

| Description of strata : | Fms. | Ft. | Ins. |
|---|---|---|---|
| Brought forward | 74 | 0 | 2 |
| Sandstone | 1 | 0 | 3 |
| Extra hard sandstone | 0 | 0 | 9 |
| Sandstone | 0 | 0 | 10 |
| Fakes and fireclay | 0 | 3 | 3 |
| Fakes and sandstone | 0 | 1 | 6 |
| Fakey blaes | 0 | 2 | 6 |
| Reddish fireclay | 2 | 2 | 6 |
| Dark blaes | 0 | 0 | 4 |
| Blue fakes | 0 | 3 | 0 |
| Light fakes and sandstone | 0 | 3 | 0 |
| Sandstone | 0 | 2 | 0 |
| Reddish fakes | 0 | 1 | 3 |
| Blue blaes and fireclay | 0 | 2 | 6 |
| Blue fakes | 0 | 1 | 2 |
| Light fakes | 0 | 4 | 2 |
| Gray fakes | 0 | 4 | 2 |
| Blue fakes and blaes | 0 | 1 | 9 |
| Light fakes | 0 | 1 | 9 |
| Sandstone | 0 | 2 | 9 |
| Light fakes | 0 | 3 | 0 |
| Blaes and iron ribs | 0 | 2 | 6 |
| **Coal** | 0 | 0 | 9 |
| Sandstone | 1 | 1 | 6 |
| Blue fakes | 0 | 2 | 3 |
| Ironstone clay band | 0 | 0 | 3 |
| Blue fakes and sandstone | 0 | 2 | 8 |
| Ironstone clay band | 0 | 0 | 2 |
| Hard sandstone | 0 | 1 | 8 |
| Blue blaes | 0 | 1 | 9 |
| Dark blaes, parroty | 0 | 0 | 9 |
| Light fakes | 0 | 3 | 7 |
| Sandstone | 0 | 4 | 6 |
| Fakes and fireclay | 0 | 3 | 4 |
| Fakes | 0 | 1 | 6 |
| White sandstone | 3 | 1 | 6 |
| Cuttry sandstone | 7 | 4 | 6 |
| **Coal** and sulphur | 0 | 0 | 2 |
| Gray sandstone | 0 | 1 | 10 |
| Hard sandstone | 0 | 3 | 0 |
| Gray fakes | 2 | 2 | 0 |
| Dark blaes | 0 | 3 | 2 |
| Ironstone balls and sulphur | 0 | 0 | 3 |
| Gray sandstone | 4 | 3 | 1 |
| Coal strains and sandstone, variegated | 1 | 3 | 0 |
| Fakes and **coal** | 0 | 0 | 10 |
| Fireclay and blaes | 0 | 4 | 0 |
| Blue fakes | 0 | 2 | 0 |
| Sandstone | 2 | 1 | 8 |
| Light fireclay | 0 | 1 | 6 |
| Light fireclay and balls | 1 | 3 | 9 |
| Sandstone | 2 | 0 | 1 |
| Fakes and sandstone | 0 | 2 | 4 |
| Light fireclay | 0 | 2 | 6 |
| **Coal** (coarse) | 0 | 0 | 9 |
| Blue fakes | 0 | 2 | 0 |
| Light fakes | 1 | 2 | 2 |
| Light gray fakes and blaes | 0 | 3 | 6 |
| Blue fakes and blaes, limey | 0 | 4 | 0 |
| **Limestone** | 0 | 1 | 2 |
| Limey fakes | 0 | 1 | 6 |
| Carry forward | 122 | 0 | 0 |

| Description of strata : | Fms. | Ft. | Ins. |
|---|---|---|---|
| Brought forward | 122 | 0 | 0 |
| Gray fakes | 0 | 3 | 10 |
| Blue fakes and blaes | 1 | 0 | 10 |
| Dark blaes | 0 | 0 | 7 |
| Fireclay and **coal** | 0 | 0 | 9 |
| Light fireclay | 0 | 2 | 8 |
| Dark fireclay and balls | 1 | 1 | 0 |
| Fakes | 0 | 0 | 8 |
| Sandstone | 1 | 3 | 5 |
| Coarse sandstone | 1 | 3 | 0 |
| Light fakes | 0 | 1 | 0 |
| Fakey sandstone | 0 | 1 | 2 |
| Limey blaes | 1 | 2 | 8 |
| Light fakes | 2 | 3 | 0 |
| Blaes and balls | 1 | 2 | 6 |
| Light fakes | 0 | 1 | 6 |
| Fakes | 1 | 0 | 0 |
| Fakes and sandstone | 1 | 1 | 4 |
| Fakes and iron balls | 0 | 2 | 8 |
| Sandstone | 0 | 2 | 0 |
| Fakes and sandstone | 2 | 0 | 0 |
| Blaes and fakes | 0 | 1 | 6 |
| Blue blaes | 1 | 2 | 2 |
| Gray **limestone** | 0 | 2 | 0 |
| Limey sandstone | 0 | 0 | 3 |
| Fakes and sandstone | 1 | 1 | 3 |
| Blue fakes and blaes | 0 | 2 | 0 |
| Fakey blaes and balls | 2 | 1 | 6 |
| Dark blaes | 1 | 4 | 6 |
| Gray **limestone** | 0 | 2 | 8 |
| **Limestone** cuttry | 0 | 3 | 1 |
| **Limestone** | 1 | 4 | 10 |
| Blue blaes | 0 | 1 | 0 |
| Fireclay and **coal** | 0 | 0 | 6 |
| White sandstone | 2 | 4 | 0 |
| Light fireclay | 0 | 2 | 5 |
| White sandstone | 0 | 5 | 0 |
| Gray fakes | 0 | 2 | 10 |
| Blue blaes | 0 | 1 | 1 |
| Gray fakes | 0 | 3 | 6 |
| White sandstone | 0 | 3 | 9 |
| Fakes and blaes | 0 | 3 | 6 |
| Soft dark blaes | 0 | 1 | 6 |
| Gray sandstone | 0 | 1 | 8 |
| Fakes and sandstone | 0 | 2 | 7 |
| Blue blaes | 2 | 5 | 6 |
| **Limestone**, gray | 0 | 1 | 6 |
| Blaes and **limestone** | 0 | 3 | 0 |
| Gray **limestone** | 0 | 3 | 6 |
| Blaes and **limestone** | 0 | 5 | 6 |
| Dark gray **limestone** | 1 | 0 | 0 |
| Fakey blaes | 0 | 0 | 3 |
| Gray sandstone | 0 | 3 | 3 |
| Gray fakes | 0 | 1 | 3 |
| Blue blaes | 0 | 0 | 9 |
| Sandstone | 1 | 2 | 0 |
| Dark fakes and blaes | 0 | 1 | 0 |
| Blue fakes | 0 | 2 | 6 |
| Sandstone | 2 | 1 | 6 |
| Coarse sandstone | 1 | 1 | 10 |
| Blue blaes and sandstone | 1 | 1 | 0 |
| Carry forward | 171 | 2 | 0 |

| Description of strata : | Fms. | Ft. | Ins. |
|---|---|---|---|
| Brought forward | 171 | 2 | 0 |
| Coarse sandstone | 2 | 0 | 2 |
| Coarse sandstone | 1 | 3 | 0 |
| Blue blaes and balls | 0 | 5 | 2 |
| Blue blaes and musse | 0 | 0 | 10 |
| Gray fakes | 0 | 3 | 6 |
| Dark blaes | 0 | 0 | 5 |
| **Coal** | 0 | 0 | 10 |
| Dark blaes and **coal** | 0 | 0 | 8 |
| Dark blaes | 0 | 1 | 0 |
| Sandstone | 1 | 3 | 6 |
| Gray fakes | 0 | 4 | 6 |
| Blue blaes | 0 | 2 | 7 |
| **Coal**, soft | 0 | 0 | 4 |
| Blue blaes | 0 | 1 | 0 |
| Dark fireclay | 0 | 0 | 8 |
| Gray sandstone | 1 | 2 | 0 |
| Gray fakes | 0 | 3 | 6 |
| Dark fakes | 0 | 1 | 6 |
| Dark gray fakes | 0 | 2 | 0 |
| **Coal** | 0 | 0 | 8 |
| **Coal** and sulphur | 0 | 0 | 2 |
| Dark fakes | 0 | 0 | 2 |
| Gray sandstone | 0 | 4 | 10 |
| Fakey sandstone | 0 | 1 | 5 |
| Dark fakes and blaes | 0 | 3 | 6 |
| Dark blaes | 0 | 1 | 2 |
| Gray sandstone | 0 | 5 | 5 |
| Gray sandstone | 0 | 3 | 6 |
| Fakes and blaes | 0 | 2 | 10 |
| Gray sandstone | 2 | 1 | 1 |
| **Coal** | 0 | 0 | 4 |
| Fakey blaes | 0 | 0 | 8 |
| White sandstone | 0 | 4 | 6 |
| Fakes and sandstone | 0 | 2 | 0 |
| Dark blue blaes | 0 | 0 | 10 |
| Carry forward | 190 | 0 | 3 |

| Description of strata : | Fms. | Ft. | Ins. |
|---|---|---|---|
| Brought forward | 190 | 0 | 3 |
| Dark gray fakes | 0 | 5 | 0 |
| White sandstone | 1 | 4 | 3 |
| Dark blaes | 0 | 0 | 11 |
| **Coal** splint | 0 | 2 | 4 |
| Fakey fireclay | 0 | 0 | 3 |
| White sandstone | 1 | 0 | 9 |
| Fakes and blaes | 0 | 0 | 10 |
| Blue fakes | 0 | 3 | 6 |
| Hard sandstone | 0 | 0 | 4 |
| Gray fakes | 0 | 2 | 8 |
| Fakes and blaes | 1 | 5 | 4 |
| Gray fakes | 2 | 0 | 10 |
| Fakes and **coal** | 0 | 1 | 6 |
| White sandstone | 0 | 4 | 7 |
| Fakes and blaes | 0 | 4 | 0 |
| Parrot **coal** | 0 | 0 | 6 |
| Fakey blaes | 0 | 2 | 0 |
| Fakes and sandstone | 2 | 1 | 2 |
| Blue blaes | 0 | 1 | 2 |
| White sandstone | 6 | 0 | 2 |
| Sandstone and coal strains | 0 | 4 | 0 |
| White sandstone | 4 | 4 | 9 |
| Blue fakes | 0 | 2 | 6 |
| Fakes and blaes | 1 | 1 | 0 |
| **Limestone** | 0 | 0 | 3 |
| Blue blaes | 0 | 1 | 0 |
| Coarse sandstone | 0 | 5 | 8 |
| Lime and sandstone | 0 | 3 | 8 |
| Hard gray coarse sandstone | 1 | 1 | 6 |
| Dark fakes and **coal** | 0 | 0 | 7 |
| Soft fireclay and blaes | 0 | 2 | 0 |
| White sandstone | 2 | 0 | 0 |
| Hard gray sandstone, limey | 0 | 0 | 9 |
| White sandstone | 1 | 4 | 6 |
| Fakey sandstone | 0 | 3 | 4 |
| Total, | 224 | 5 | 10 |

This deep bore furnishes important evidence as to the sequence of beds below the Seven Feet Seam down to the upper limestones at the top of the Marine Limestone series. The Coals of the Byre Burn group (see page 858) were not met with in this intervening group, and it is therefore probable, as already suggested, that the latter represents, in part at least, the Millstone Grit division.

## ix. *Byre Burn Coal Group* (*Middle Coal-measures*).

The members of this subdivision are exposed in the Byre Burn that joins the Esk, on the east bank, about a mile north of Canonbie village, where they consist of sandstones, shales, fireclays, and coal-seams. In 1816 a bore was sunk through this group, a copy of the journal of which is subjoined.

| | Ft. | Ins. |
|---|---|---|
| Till or alluvial clay | 15 | 0 |
| Blue **limestone** | 1 | 0 |
| Blue metals | 15 | 0 |
| White freestone | 2 | 0 |
| Main **coal** (deficient)* | 0 | 4 |
| Fireclay | 0 | 3 |
| White freestone | 30 | 0 |
| Blue metal | 1 | 0 |
| ¾ **coal** (deficient)† | 1 | 0 |
| Fireclay | 1 | 6 |
| Gray beds of stone and blaes | 15 | 0 |
| Craw **coal** | 0 | 8 |
| Fireclay | 0 | 1 |
| White stone | 1 | 6 |
| Carry forward | 84 | 4 |

| | Ft. | Ins. |
|---|---|---|
| Brought forward | 84 | 4 |
| Gray beds | 34 | 0 |
| White stone | 2 | 0 |
| Craw **coal** | 1 | 0 |
| Fireclay | 1 | 0 |
| Ironstone | 1 | 2 |
| Gray beds | 30 | 0 |
| White freestone | 2 | 0 |
| Craw **coal** | 1 | 6 |
| Fireclay | 1 | 0 |
| White freestone | 15 | 0 |
| Lime **coal** { top bed | 1 | 0 |
| Lime **coal** { metal | 3 | 0 |
| Lime **coal** { bottom bed | 3 | 0 |
| | 180 | 0 |

In the above section the deficient thicknesses of the Main and Three-Quarter Seams are due to the bore having passed through old workings.

In the lower part of the Byre Burn, close to the Esk, the strata dip to the south-east at angles varying from 20° to 25°, while further up, towards the railway viaduct, they are thrown into an anticline. On their western side they are bounded by a fault that enters the Esk a few yards above the foot of Byre Burn and runs down the river channel for a distance of 200 yards, thereafter ascending the west bank. By means of this dislocation they are brought in contact with strata referred to the upper part of the Marine Limestone series. The limits of this subdivision are not clearly defined, but the beds can be traced down the east bank of the Esk at Byreburnfoot, till they are abruptly cut off by the east and west fault that brings down the red sandstones and shales of the Upper Coal-measures. The area occupied by the Byre Burn group, at present known, measures about a quarter of a square mile.

### x. *Red Sandstone Group (Upper Coal-measures).*

The red sandstones and shales that form the highest division of the Carboniferous system in Eskdale and Liddisdale are well seen in the Esk between Byreburnfoot and Canonbie bridge, and in the Liddel above and below the junction of Archerbeck with that river. Along their northern margin, as already indicated, they are bounded by a powerful east and west fault, which brings them successively in contact with the Marine Limestone series in the Liddel Water, with the Lower Coal-measures at Rowanburn, and with the Middle Coal-measures in the Esk (see Plate I.). The fault is admirably seen in the Liddel, where the strata on either side form a high cliff, and also in the Rowanburn close to the colliery. In the Esk the general dip of the beds is to the south or south-east, at angles varying from 15° to 35°. In the Liddel and in Archerbeck, however, there is evidence of folding and faulting of the strata, for they are inclined in various directions, and the lines of dislocation are visible in the stream sections.

* Usually 4 feet 10 inches, with 4 inches metal. † Usually 3 feet thick.

Lithologically, as Mr Binney pointed out, the sandstones, marls, and clayey shales of this Carboniferous subdivision are distinguishable from the Triassic rocks to the south. Much of the red and purple colour of the former is due to staining, and they lack the rich brick-red hue of the Triassic sandstones. This contrast is very apparent in the Esk. Reference has already been made to the fact that Mr Binney detected in the Esk at Knottyholm a bed of *Spirorbis* limestone, six inches thick, in association with red and purple shales, clays, bands of grit, and two seams of calcareous ironstone.

The plants obtained by Mr Macconochie from the red and greenish shales in the upper part of this series at Jockie's Syke, near Riddings Junction, have been unhesitatingly referred by Mr Kidston to the horizon of the Upper Coal-measures.* In the absence of determinable plants from the members of this group exposed in the Esk section, he is at present unable to determine whether the latter belong to the Upper Transition series of England or to the Upper Coal-measures.

Along their southern margin these Upper Carboniferous sandstones are covered unconformably by the Trias, the boundary between the two being a sinuous line. As shown on the sketch map (Plate I.), they occupy on the Scottish side a narrow belt about three miles in length from the Liddel westwards beyond the Esk. Owing to the thick accumulation of drift (boulder clay and gravel), their limits west of the Esk cannot be definitely fixed, but it is probable that they extend as far as Bulmans Knowe, which is about a mile west of that river. On this assumption the area which they cover in Scotland is two square miles.

A question of great economic importance arises in connection with this highest division of the Carboniferous system in the border region, which relates to the existence of a concealed coalfield underneath the area occupied by these sandstones. There is no evidence at present known to us pointing to any unconformability at their base; indeed, all the available data indicate continuous deposition from the White sandstones and cementstones to the top of the system. Under these circumstances it is obvious that both the valuable coal-seams of Rowanburn and those of Byre Burn might naturally be found below these sandstones. With the view of testing this question, the representatives of His Grace the Duke of Buccleuch sank two deep bores. The first was put down at Rowanburn about 200 yards south of the great fault that bounds these sandstones on the north (see Plate I.). A copy of the journal of this bore is given below:—

* *Summary of Progress, H.M. Geological Survey*, 1902, p. 214. *Trans. Roy. Soc. Edin.*, vol. xl. pp. 741–833.

SECTION OF STRATA BORED BY "DIAMOND DRILL" THROUGH OVERLYING RED SANDSTONE FORMATION INTO COAL MEASURES AT ROWANBURN, NEAR CANONBIE COLLIERY. BORING COMMENCED 7TH MARCH 1889, FINISHED 7TH MARCH 1890.

| | Fms. | Ft. | Ins. |
|---|---|---|---|
| Surface sand | 0 | 4 | 6 |
| Sand and gravel | 0 | 2 | 6 |
| Red muddy clay | 3 | 3 | 0 |
| ,, sandy clay (firm) | 0 | 4 | 0 |
| ,, muddy clay | 1 | 0 | 6 |
| ,, fakes, broken (thin beds laminated) | 2 | 4 | 0 |
| ,, soft fireclay | 0 | 3 | 6 |
| ,, soft sandstone | 1 | 2 | 0 |
| ,, blaes | 0 | 2 | 0 |
| ,, fireclay | 0 | 1 | 6 |
| ,, sandstone, soft | 1 | 3 | 6 |
| ,, fireclay and blaes | 1 | 0 | 6 |
| ,, sandstone, soft | 0 | 5 | 0 |
| ,, blaes, soft | 1 | 1 | 0 |
| ,, fakes | 0 | 2 | 0 |
| ,, light fakes and fireclay | 1 | 4 | 6 |
| ,, fakey sandstone | 0 | 3 | 6 |
| ,, sandstone | 1 | 1 | 6 |
| ,, fakes | 0 | 1 | 0 |
| ,, fakes and fireclay | 0 | 5 | 0 |
| ,, fakes | 0 | 2 | 0 |
| ,, fireclay | 0 | 2 | 3 |
| ,, sandstone | 0 | 2 | 6 |
| ,, fakes and fireclay | 0 | 3 | 4 |
| ,, fakes | 0 | 2 | 3 |
| ,, fakes and blaes | 0 | 3 | 9 |
| ,, fireclay | 0 | 2 | 6 |
| ,, fakes | 0 | 2 | 4 |
| Light red fakes | 1 | 2 | 6 |
| Gray sandstone (solid) | 12 | 2 | 10 |
| Red blaes | 3 | 0 | 0 |
| ,, fakes and blaes | 1 | 3 | 2 |
| ,, fakes | 1 | 4 | 0 |
| ,, fakes and sandstone | 1 | 3 | 6 |
| ,, soft blaes | 0 | 2 | 0 |
| ,, sandstone | 5 | 2 | 0 |
| ,, blaes * | 0 | 1 | 6 |
| ,, sandstone | 1 | 2 | 0 |
| ,, fakes | 0 | 5 | 6 |
| ,, fakes and sandstone | 6 | 0 | 6 |
| ,, fakes | 0 | 1 | 0 |
| ,, fakes and sandstone | 2 | 0 | 0 |
| ,, blaes | 0 | 1 | 6 |
| Gray sandstone | 3 | 0 | 6 |
| Red irony sandstone | 0 | 0 | 6 |
| Brown sandstone | 0 | 3 | 9 |
| Red sandstone (conglomerate) | 0 | 3 | 4 |
| ,, blaes (variegated) | 0 | 4 | 0 |
| Brown irony fakes | 0 | 0 | 2 |
| Red fakes (variegated) | 0 | 1 | 10 |
| Brown fakes | 1 | 4 | 7 |
| Carry forward | 70 | 0 | 7 |

| | Fms. | Ft. | Ins. |
|---|---|---|---|
| Brought forward | 70 | 0 | 7 |
| Red fireclay | 4 | 1 | 8 |
| ,, blaes | 2 | 2 | 0 |
| ,, blaes | 1 | 5 | 0 |
| ,, fakes | 0 | 3 | 9 |
| ,, sandstone | 0 | 4 | 9 |
| ,, fakes and sandstone | 2 | 3 | 9 |
| ,, blaes (variegated) | 1 | 2 | 0 |
| Brown irony fakes | 0 | 0 | 2 |
| Red sandy fakes (variegated) | 0 | 2 | 0 |
| ,, sandy fakes (limey) | 0 | 5 | 0 |
| ,, blaes (limey) | 1 | 1 | 2 |
| ,, blaes, hard (limey) | 3 | 2 | 10 |
| Light red fakes | 0 | 4 | 0 |
| Light red fakes and iron balls | 0 | 3 | 9 |
| Red fakes and fireclay | 0 | 4 | 0 |
| ,, fakes and blaes | 1 | 1 | 0 |
| ,, fakes | 0 | 3 | 0 |
| ,, blaes | 2 | 1 | 8 |
| ,, fakes and blaes | 1 | 0 | 0 |
| ,, and green fakes and blaes | 1 | 5 | 0 |
| ,, irony blaes | 0 | 0 | 2 |
| Light grey blaes | 0 | 1 | 10 |
| ,, bluish grey blaes | 1 | 3 | 6 |
| Reddish fireclay and ochre | 2 | 1 | 8 |
| Red fireclay | 2 | 4 | 2 |
| Hard white sandstone | 1 | 5 | 0 |
| Reddish fakes and sandstone | 1 | 4 | 0 |
| Red fakes | 0 | 4 | 0 |
| Fakes and sandstone | 1 | 2 | 0 |
| Gray sandstone | 0 | 2 | 0 |
| Reddish fakes and sandstone | 3 | 5 | 9 |
| Bluish fakes | 0 | 2 | 0 |
| Red fakes and sandstone | 0 | 1 | 0 |
| ,, blaes (variegated) | 0 | 5 | 0 |
| ,, hard blaes | 1 | 5 | 8 |
| Reddish fakes and blaes | 2 | 0 | 0 |
| Light red fakes and fireclay | 1 | 0 | 6 |
| Red sandstone | 0 | 5 | 0 |
| Reddish blaes | 0 | 4 | 0 |
| Red fakes | 0 | 1 | 0 |
| Sandstone (hard, white) | 0 | 1 | 2 |
| Light blaes | 1 | 2 | 8 |
| Extra hard gray sandstone | 0 | 1 | 0 |
| Gray fakes | 0 | 1 | 3 |
| Light fireclay and blaes | 0 | 2 | 0 |
| Red fireclay and blaes | 0 | 5 | 2 |
| Red and brownish blaes | 0 | 4 | 7 |
| Red and gray sandstone | 1 | 3 | 0 |
| Sandstone (conglomerate) | 0 | 3 | 0 |
| Blaes (variegated) | 1 | 2 | 6 |
| Carry forward | 130 | 3 | 8 |

* *Note.*—From 53 fathoms to 83 fathoms thin seams of gypsum were met with, not exceeding $\frac{1}{4}$ inch thick.

| | Fms. | Ft. | Ins. |
|---|---|---|---|
| Brought forward | 130 | 3 | 8 |
| Red fakes and sandstone | 0 | 1 | 10 |
| Red blaes | 0 | 5 | 0 |
| Light gray fireclay | 0 | 5 | 7 |
| Red fakes and blaes | 1 | 2 | 1 |
| ,, fakes and sandstone | 0 | 2 | 3 |
| ,, blaes | 0 | 5 | 0 |
| ,, sandstone (solid) | 1 | 0 | 3 |
| Soft fireclay | 0 | 3 | 0 |
| Blaes (hard) | 0 | 2 | 5 |
| Fireclay and ochre | 0 | 3 | 0 |
| Red sandstone and ochre | 1 | 1 | 0 |
| White(ish) sandstone | 0 | 3 | 0 |
| Reddish fakes (variegated) | 2 | 3 | 8 |
| Red and white sandstone | 1 | 2 | 0 |
| Red blaes (variegated) | 0 | 2 | 0 |
| ,, sandstone | 0 | 3 | 0 |
| ,, fakes | 0 | 2 | 9 |
| ,, sandstone | 0 | 2 | 0 |
| Extra hard gray sandstone | 0 | 0 | 9 |
| Red sandstone | 0 | 2 | 6 |
| ,, fakes and blaes | 0 | 3 | 0 |
| Extra hard gray sandstone | 0 | 1 | 0 |
| Red sandstone | 1 | 5 | 0 |
| ,, fakes | 0 | 4 | 0 |
| ,, fakes and sandstone | 4 | 1 | 0 |
| ,, blaes, variegated | 0 | 1 | 6 |
| ,, and grayish sandstone | 0 | 4 | 3 |
| ,, fakes and sandstone | 1 | 3 | 0 |
| ,, blaes, soft | 0 | 2 | 6 |
| ,, fakes | 0 | 1 | 6 |
| Reddish fireclay and blaes | 0 | 2 | 6 |
| Red sandstone | 0 | 5 | 0 |
| ,, blaes | 0 | 3 | 0 |
| ,, fakes and sandstone | 1 | 2 | 0 |
| ,, and gray sandstone | 0 | 3 | 8 |
| ,, sandstone | 0 | 2 | 0 |
| Extra hard sandstone | 0 | 1 | 2 |
| Red and white sandstone | 1 | 1 | 0 |
| ,, blaes | 0 | 5 | 1 |
| ,, and gray fakes and sandstone | 0 | 5 | 6 |
| ,, blaes | 0 | 1 | 3 |
| ,, fakes | 0 | 2 | 0 |
| Sandstone, hard gray | 0 | 1 | 2 |
| Red blaes | 0 | 0 | 11 |
| Sandstone, gray, extra hard | 0 | 1 | 6 |
| Sandstone (whitish) | 0 | 1 | 0 |
| Sandstone (extra hard) | 0 | 0 | 6 |
| Red fakes and sandstone | 0 | 5 | 3 |
| ,, blaes | 0 | 2 | 0 |
| ,, fakes and sandstone | 0 | 5 | 7 |
| ,, blaes | 0 | 1 | 0 |
| ,, and gray sandstone | 0 | 2 | 6 |
| ,, blaes | 0 | 1 | 9 |
| ,, and gray sandstone | 1 | 2 | 0 |
| ,, fakes | 0 | 1 | 6 |
| ,, blaes | 0 | 5 | 6 |
| ,, blaes (variegated) | 0 | 2 | 9 |
| Light bluish blaes | 0 | 4 | 3 |
| Red and light blaes | 1 | 1 | 7 |
| blaes | 1 | 3 | 9 |
| Carry forward | 173 | 6 | 2 |

| | Fms. | Ft. | Ins. |
|---|---|---|---|
| Brought forward | 173 | 6 | 2 |
| Red and light blaes | 2 | 0 | 6 |
| ,, fakes and blaes | 1 | 1 | 0 |
| Sandstone | 0 | 2 | 6 |
| Red blaes | 0 | 3 | 0 |
| Light fakes and blaes | 0 | 1 | 6 |
| Red fakes and sandstone | 2 | 1 | 4 |
| Light fakes and sandstone | 0 | 4 | 0 |
| Red fakes and blaes | 1 | 0 | 0 |
| Blue blaes | 0 | 0 | 4 |
| Light blaes | 0 | 4 | 6 |
| Blaes, variegated | 0 | 3 | 9 |
| Red blaes | 1 | 3 | 0 |
| ,, and light blaes | 0 | 2 | 8 |
| Bluish fireclay | 0 | 3 | 4 |
| Light fakes | 0 | 3 | 0 |
| Blaes and ochre | 0 | 2 | 3 |
| Red and light blaes | 0 | 4 | 0 |
| ,, fireclay and blaes | 1 | 3 | 0 |
| Blue fireclay (*upper bed of coal measures, A. Bowie*) | 0 | 5 | 0 |
| Sandstone | 0 | 3 | 0 |
| Red and bluish fakes | 0 | 3 | 6 |
| Sandstone (extra hard) | 0 | 0 | 6 |
| Blue fireclay and blaes | 0 | 3 | 7 |
| Black blaes | 0 | 0 | 5 |
| Blue fireclay and ironstone balls | 0 | 4 | 0 |
| Light fireclay and balls | 0 | 0 | 7 |
| Blaes and **coal** | 0 | 0 | 2 |
| 1st **coal** | 0 | 0 | 5 |
| Blaes and **coal** | 0 | 0 | 5 |
| Fireclay | 0 | 0 | 6 |
| Blue fakes | 2 | 2 | 6 |
| Fireclay (soft, reddish) | 1 | 0 | 0 |
| Fakes (gray) | 0 | 5 | 4 |
| Blue blaes | 0 | 1 | 6 |
| Fakes and sandstone | 1 | 0 | 0 |
| Blue blaes and balls | 0 | 4 | 0 |
| Gray fakes | 0 | 3 | 7 |
| Dark blaes and balls | 1 | 4 | 0 |
| Coaly blaes | 0 | 0 | 5 |
| Black shelly blaes | 0 | 1 | 0 |
| 2nd **coal** | 0 | 0 | 6 |
| Dark blaes | 0 | 0 | 2 |
| Light fireclay | 0 | 3 | 0 |
| Irony fireclay | 0 | 1 | 0 |
| Light fakes and fireclay | 0 | 5 | 0 |
| Gray fakes | 0 | 4 | 6 |
| Blue blaes and balls | 0 | 1 | 6 |
| Ironstone ball | 0 | 0 | 1 |
| Blue blaes | 0 | 0 | 4 |
| 3rd **coal** | 0 | 1 | 0 |
| Dark blaes | 0 | 0 | 4 |
| Sandstone | 0 | 4 | 3 |
| Blue blaes | 0 | 1 | 3 |
| Sandstone | 0 | 0 | 8 |
| Dark blaes | 0 | 0 | 10 |
| Ironstone | 0 | 0 | 3 |
| Dark blaes | 0 | 1 | 0 |
| Blue fakes | 1 | 0 | 0 |
| Blue blaes and ironstone balls | 1 | 2 | 3 |
| Carry forward | 208 | 2 | 2 |

| | Fms. | Ft. | Ins. |
|---|---|---|---|
| Brought forward | 208 | 2 | 2 |
| Dark blaes | 0 | 0 | 2 |
| 4th **coal** | 0 | 0 | 6 |
| Dark fireclay | 0 | 0 | 7 |
| Light fireclay and ironstone balls | 0 | 2 | 0 |
| Red and blue fakes and sandstone | 0 | 4 | 0 |
| Red and white sandstone | 5 | 0 | 2 |
| Blue blaes and ironstone balls | 0 | 3 | 0 |
| Blue fakes and blaes | 4 | 5 | 4 |
| Blue blaes and ironstone balls | 1 | 1 | 8 |
| Light fireclay | 0 | 1 | 6 |
| Light blue blaes and ironstone balls | 2 | 2 | 7 |
| Blue fakes and blaes | 0 | 2 | 0 |
| Blue blaes | 0 | 3 | 3 |
| Fakes and sandstone | 2 | 5 | 7 |
| Dark blaes | 0 | 0 | 10 |
| 5th **coal** | 0 | 0 | 5 |
| Dark blaes | 0 | 0 | 2 |
| Light fireclay | 0 | 2 | 2 |
| Dark fireclay | 0 | 1 | 5 |
| Blaes and red balls | 0 | 0 | 7 |
| Red sandstone | 0 | 1 | 6 |
| Red and white sandstone | 2 | 0 | 0 |
| Dark fakes | 0 | 2 | 0 |
| Blaes and balls | 1 | 2 | 4 |
| 6th **coal** | 0 | 1 | 8 |
| Light fireclay | 0 | 3 | 3 |
| Dark fakes | 1 | 1 | 3 |
| Red and gray sandstone | 0 | 3 | 6 |
| Reddish fakes | 0 | 0 | 9 |
| Gray and white sandstone | 3 | 1 | 6 |
| Dark gray fakes | 0 | 2 | 6 |
| Dark blaes | 0 | 2 | 4 |
| 7th **coal** | 0 | 1 | 10 |
| Light fireclay | 0 | 1 | 0 |
| Carry forward | 239 | 5 | 6 |

| | Fms. | Ft. | Ins. |
|---|---|---|---|
| Brought forward | 239 | 5 | 6 |
| Light fireclay and ironstone balls | 0 | 1 | 5 |
| Gray fakes and balls | 0 | 2 | 0 |
| Fakes and sandstone | 1 | 3 | 7 |
| White sandstone | 1 | 2 | 6 |
| Dark blue blaes | 0 | 2 | 7 |
| Ironstone ball | 0 | 0 | 2 |
| Dark blaes | 2 | 1 | 1 |
| 8th **coal**, soft | 0 | 1 | 2 |
| Dark fireclay | 0 | 1 | 0 |
| Dark blaes | 1 | 1 | 10 |
| 9th **coal** | 0 | 1 | 6 |
| Light fireclay | 0 | 1 | 2 |
| Light fireclay | 0 | 4 | 0 |
| Blaes | 2 | 0 | 2 |
| Sandstone (white) | 0 | 1 | 0 |
| Fakes and sandstone (white) | 0 | 3 | 0 |
| Blaes (blue) | 0 | 2 | 2 |
| Blaes (black-coaly) | 0 | 0 | 9 |
| Fireclay (light) | 0 | 1 | 7 |
| Sandstone (gray) | 0 | 4 | 6 |
| Fakes (gray) | 0 | 0 | 9 |
| Sandstone (white and hard) | 1 | 2 | 9 |
| Fakes (gray) | 0 | 1 | 3 |
| Sandstone (white) | 2 | 1 | 10 |
| Blaes (black) | 0 | 0 | 4 |
| 10th **coal** (soft) | 0 | 2 | 5 |
| Fakes and fireclay | 0 | 0 | 6 |
| Sandstone (white) | 0 | 1 | 1 |
| Sandstone, white and hard | 0 | 0 | 10 |
| Blaes (dark) | 0 | 1 | 1 |
| Blue blaes and ironstone balls | 4 | 0 | 0 |
| Mussel band | 0 | 0 | 10 |
| Blaes, black (with ironstone balls) | 0 | 3 | 3 |
| Blaes, blue | 0 | 2 | 0 |
| Total, | 263 | 1 | 7 |

In the Rowanburn bore ten coal-seams were pierced: four under one foot thick, five ranging from one to two feet, and one measuring two feet five inches, which was reached at a depth of 257 fathoms.

At a later date the second bore was sunk on the west bank of the Esk, near the forge at Canonbie bridge, about half a mile to the south of the great fault that bounds the Carboniferous Red Sandstones on the north side (see Plate I.). A copy of the journal of this bore is subjoined:—

SECTION OF STRATA BORED BY "DIAMOND DRILL" THROUGH OVERLYING RED SANDSTONE FORMATION INTO COAL-MEASURES AT WEST SIDE OF RIVER ESK, NEAR FORGE. COMMENCED JUNE 1892, FINISHED 1893.

| | Fms. | Ft. | Ins. |
|---|---|---|---|
| Sand | 1 | 1 | 3 |
| Coarse gravel | 1 | 0 | 0 |
| Red fireclay and blaes | 1 | 1 | 9 |
| Red sandstone | 3 | 0 | 0 |
| Red sandstone (fakey) | 1 | 0 | 0 |
| Red sandstone | 2 | 1 | 0 |
| Red fakes and blaes | 0 | 4 | 6 |
| Red sandstone | 12 | 2 | 4 |
| Soft fakes and fireclay | 0 | 2 | 6 |
| Fakes and blaes | 0 | 2 | 3 |
| Blaes | 3 | 4 | 4 |
| Reddish sandstone | 3 | 0 | 10 |
| Red fakes | 0 | 3 | 6 |
| Red blaes | 0 | 5 | 2 |
| Red blaes (hard) | 0 | 5 | 9 |
| Red blaes (soft) | 1 | 3 | 7 |
| Fakes and blaes | 0 | 5 | 2 |
| Red sandstone | 4 | 0 | 10 |
| Sandstone (conglomerate) | 0 | 2 | 0 |
| Red sandstone | 0 | 2 | 2 |
| Red fireclay | 0 | 2 | 0 |
| Red blaes | 1 | 2 | 6 |
| Fireclay and blaes | 1 | 0 | 6 |
| Red blaes | 1 | 0 | 0 |
| Red fakey sandstone | 0 | 3 | 0 |
| Fireclay and blaes | 1 | 0 | 0 |
| Red blaes | 0 | 4 | 2 |
| Red blaes and fireclay | 1 | 0 | 5 |
| Blaes | 0 | 3 | 7 |
| Red sandstone | 4 | 3 | 6 |
| Red blaes | 2 | 3 | 3 |
| Red fakes | 0 | 5 | 10 |
| Gray sandstone | 0 | 1 | 0 |
| Red blaes | 3 | 0 | 8 |
| Red blaes (hard) | 2 | 1 | 11 |
| Red and greenish blaes | 0 | 1 | 0 |
| Red blaes | 0 | 1 | 9 |
| Red fakes | 1 | 1 | 4 |
| Red fakes and sandstone | 1 | 1 | 2 |
| Red fakes and blaes | 1 | 2 | 0 |
| Red blaes | 1 | 0 | 6 |
| Red fakes and blaes | 1 | 0 | 0 |
| Red fakes | 0 | 4 | 0 |
| Red fakes and sandstone | 2 | 1 | 0 |
| Red blaes | 0 | 5 | 2 |
| Fakes and blaes, red | 1 | 0 | 0 |
| Red blaes | 1 | 0 | 0 |
| Fakes (hard, coarse, conglomerate) | 0 | 4 | 0 |
| Red blaes (hard) | 0 | 5 | 0 |
| Red fireclay and blaes | 0 | 4 | 10 |
| Fakes (hard) | 1 | 2 | 5 |
| Fireclay and blaes | 0 | 5 | 0 |
| Red blaes (hard) | 2 | 1 | 6 |
| Red and light blaes | 3 | 2 | 4 |
| Carry forward | 83 | 4 | 3 |

| | Fms. | Ft. | Ins. |
|---|---|---|---|
| Brought forward | 83 | 4 | 3 |
| Red blaes | 1 | 3 | 0 |
| Blue fakes and blaes | 2 | 5 | 2 |
| Light reddish fireclay | 1 | 4 | 6 |
| Gray sandstone | 1 | 0 | 6 |
| Fakes and fireclay | 0 | 2 | 6 |
| Fakey sandstone | 1 | 0 | 0 |
| Gray sandstone | 1 | 5 | 0 |
| Reddish sandstone | 1 | 3 | 0 |
| Red sandstone | 8 | 5 | 2 |
| White sandstone | 0 | 3 | 0 |
| Red blaes and soft partings | 5 | 2 | 9 |
| Red fakey blaes | 0 | 2 | 5 |
| Red fireclay and blaes | 0 | 2 | 9 |
| Black blaes | 0 | 0 | 4 |
| Red blaes | 0 | 0 | 6 |
| Reddish sandstone | 0 | 5 | 0 |
| Red blaes (fakey) | 1 | 2 | 0 |
| Red sandstone | 0 | 2 | 10 |
| Red blaes (fakey) | 1 | 0 | 9 |
| Red sandstone | 0 | 4 | 9 |
| Green fireclay | 0 | 3 | 0 |
| Black blaes | 0 | 0 | 4 |
| Light fireclay | 0 | 1 | 4 |
| 1st **coal** | 0 | 0 | 7 |
| Light greenish fireclay | 0 | 2 | 8 |
| Dark fakes and coal | 0 | 0 | 5 |
| Dark fakes | 0 | 2 | 0 |
| Limey sandstone | 0 | 3 | 6 |
| **Limestone** (inferior) | 1 | 2 | 9 |
| Green fireclay and balls of ironstone | 0 | 3 | 9 |
| Red and greenish fireclay | 1 | 3 | 0 |
| Greenish blaes | 0 | 4 | 8 |
| Red blaes | 1 | 2 | 4 |
| Red and green blaes | 1 | 4 | 7 |
| Limey blaes | 0 | 5 | 5 |
| Red and green blaes | 2 | 0 | 0 |
| Light greenish blaes and balls | 1 | 3 | 3 |
| Light blaes | 1 | 1 | 3 |
| 2nd **coal** | 0 | 1 | 2 |
| Light fireclay | 0 | 1 | 8 |
| Light fakes | 0 | 1 | 6 |
| Sandstone | 1 | 1 | 0 |
| Light bluish blaes | 0 | 1 | 6 |
| 3rd **coal** | 0 | 1 | 4 |
| **Coal** and sulphur | 0 | 1 | 1 |
| Dark fakes | 0 | 0 | 4 |
| Light fakes | 1 | 0 | 0 |
| Red and greenish fakes | 0 | 4 | 0 |
| Bluish fakes | 0 | 2 | 9 |
| Red and green blaes (variegated) | 1 | 5 | 0 |
| Red and green blaes | 1 | 5 | 4 |
| Red fakes and blaes | 1 | 2 | 4 |
| Red and green blaes | 4 | 0 | 1 |
| Carry forward | 145 | 2 | 1 |

| | Fms. | Ft. | Ins. |
|---|---|---|---|
| Brought forward | 145 | 2 | 1 |
| Blue blaes | 0 | 4 | 4 |
| Bluish blaes (and strains of ochre) | 1 | 0 | 9 |
| Red blaes | 0 | 3 | 4 |
| Dark blaes | 0 | 0 | 4 |
| Gray fakes | 0 | 0 | 9 |
| Red and greenish fakes | 0 | 3 | 8 |
| Red and white sandstone | 0 | 2 | 0 |
| Blaes and ochre | 0 | 1 | 0 |
| Red blaes | 0 | 2 | 0 |
| Red blaes and ochre | 1 | 3 | 11 |
| Red blaes (variegated) | 0 | 4 | 6 |
| Red blaes | 0 | 5 | 0 |
| Red blaes, variegated | 2 | 4 | 0 |
| Sandstone | 0 | 4 | 6 |
| Red and white blaes (variegated) | 3 | 4 | 4 |
| Red sandstone | 1 | 4 | 7 |
| Red and white sandstone | 1 | 2 | 6 |
| Blaes (variegated) | 0 | 4 | 0 |
| Red sandstone | 1 | 1 | 0 |
| Red blaes | 0 | 3 | 0 |
| Red and white sandstone | 0 | 2 | 3 |
| Red sandstone | 1 | 2 | 6 |
| Blaes, variegated | 0 | 1 | 6 |
| Red sandstone | 0 | 4 | 10 |
| Blaes (variegated) | 0 | 3 | 2 |
| Fireclay (variegated) | 0 | 5 | 0 |
| Fakes (hard) | 0 | 2 | 0 |
| Red sandstone | 1 | 3 | 7 |
| Red blaes | 0 | 2 | 6 |
| Red and white sandstone | 0 | 5 | 6 |
| Red fireclay | 0 | 5 | 0 |
| Fireclay and ochre | 1 | 0 | 0 |
| Red and white blaes | 0 | 5 | 0 |
| Red fireclay | 0 | 4 | 0 |
| Red blaes | 1 | 0 | 0 |
| Red and lightish blaes | 1 | 1 | 3 |
| Red and white sandstone | 1 | 4 | 6 |
| Red and white fakes and blaes | 1 | 0 | 6 |
| Red fireclay blaes | 1 | 1 | 8 |
| Red and light blaes and ochre | 2 | 1 | 10 |
| Red and white sandstone | 0 | 2 | 0 |
| Red and light blaes | 1 | 3 | 10 |
| Red and white fakes and sandstone | 0 | 3 | 8 |
| Red and light blaes | 0 | 4 | 0 |
| Red and white sandstone | 1 | 0 | 0 |
| Fakey blaes | 0 | 1 | 3 |
| White sandstone | 0 | 1 | 0 |
| Fakey blaes | 0 | 2 | 9 |
| Light blaes | 1 | 4 | 0 |
| White sandstone | 3 | 0 | 0 |
| Red and light blaes | 1 | 0 | 0 |
| Red and light fireclay and blaes | 5 | 0 | 0 |
| Light blaes | 0 | 1 | 6 |
| Red blaes | 0 | 3 | 0 |
| Light fireclay | 0 | 0 | 6 |
| Dark blaes | 0 | 1 | 2 |
| Light fireclay | 0 | 5 | 0 |
| Red fireclay | 0 | 5 | 6 |
| Red and light fireclay | 1 | 0 | 6 |
| Carry forward | 204 | 1 | 10 |

| | Fms. | Ft. | Ins |
|---|---|---|---|
| Brought forward | 204 | 1 | 10 |
| Bluish fireclay | 1 | 2 | 6 |
| Light blaes | 0 | 5 | 6 |
| Light fireclay | 0 | 4 | 3 |
| Dark blaes | 0 | 1 | 2 |
| Dark blaes and coal | 0 | 0 | 6 |
| Dark fireclay | 0 | 1 | 6 |
| Light fireclay | 1 | 3 | 7 |
| White sandstone | 1 | 2 | 3 |
| Greenish fakes and sandstone | 1 | 1 | 8 |
| Greenish fakes and blaes | 1 | 1 | 7 |
| 4th coal (soft) | 0 | 0 | 7 |
| Blue fireclay | 0 | 1 | 0 |
| Light fireclay | 1 | 0 | 0 |
| Fakey sandstone | 0 | 5 | 4 |
| Blue fakes | 0 | 2 | 0 |
| Light fakey sandstone | 0 | 1 | 10 |
| Blue fakes and hard ribs | 2 | 2 | 0 |
| Light fakes | 1 | 0 | 0 |
| Dark blaes | 0 | 4 | 0 |
| Light fakes | 1 | 2 | 0 |
| Light sandstone | 1 | 5 | 0 |
| Fakes and sandstone | 0 | 5 | 6 |
| Blue blaes and fireclay | 0 | 2 | 0 |
| Light fireclay (soft running) | 0 | 5 | 8 |
| Light fakes | 0 | 1 | 8 |
| Dark fakes and sandstone | 3 | 2 | 4 |
| White sandstone | 0 | 0 | 10 |
| Sandstone and coal strains | 0 | 0 | 6 |
| Fakey sandstone | 0 | 1 | 8 |
| Blue blaes | 0 | 0 | 4 |
| White sandstone | 0 | 2 | 6 |
| Blue blaes | 0 | 0 | 6 |
| White sandstone | 0 | 3 | 10 |
| Fireclay and coal | 0 | 0 | 9 |
| Fakes and fireclay | 1 | 0 | 9 |
| Fakey sandstone | 2 | 0 | 0 |
| White sandstone | 1 | 5 | 8 |
| Light fakes | 1 | 1 | 6 |
| Dark blaes and balls (ironstone) | 0 | 5 | 6 |
| 5th coal | 0 | 0 | 9 |
| Dark blaes | 0 | 3 | 0 |
| Light fireclay | 0 | 2 | 3 |
| Light fakes | 1 | 1 | 0 |
| White sandstone (coarse) | 3 | 2 | 0 |
| Fakes and sandstone | 0 | 5 | 6 |
| Gray fakes | 0 | 1 | 6 |
| Blaes and ironstone ribs | 0 | 3 | 6 |
| Dark blaes | 0 | 1 | 6 |
| 6th coal | 0 | 1 | 3 |
| 6th blaes (black) | 0 | 0 | 3 |
| 6th coal (splint) | 0 | 0 | 9 |
| Dark fireclay | 0 | 0 | 6 |
| Dark blaes | 0 | 1 | 6 |
| Dark fakes | 0 | 4 | 6 |
| Dark blue blaes | 1 | 5 | 10 |
| 7th coal | 0 | 1 | 9 |
| Bluish fireclay | 0 | 4 | 0 |
| Fakes and sandstone | 0 | 3 | 7 |
| Total depth, | 250 | 4 | 6 |

A glance at the journal of the Forge bore shows that seven coal-seams were passed through, ranging in thickness from seven inches to two feet, the lowest seam being reached at a depth of 249 fathoms.

The evidence obtained from these two bores demonstrates the existence of thin coal-seams underneath the Carboniferous red sandstones of Canonbie. Though they cannot be correlated with the known Canonbie coals, it is not improbable that they may belong to the upper part of the Byre Burn group, the whole sequence of which has not been proved.

In the sheet of vertical sections (Plate II.), illustrating diagrammatically the more important bores put down in the Canonbie district, we have shown what we believe to be the relative stratigraphical position of the strata in each bore in the Carboniferous system. In our opinion, had the bores at the Forge or Rowanburn, within the area of Carboniferous red sandstone, been sunk to a sufficient depth, they would have passed through, in turn, the Middle Coal-measures of Byre Burn, the Lower Coal-measures of Rowanburn, the Upper Limestones and Kilnholm coals in the Rowanburn bore, and eventually the massive Lower Limestones shown in the Catsbit section.*

## III. Description of Horizontal Sections.

1. *Buchtknowe to Larriston Fells and Kershope Burn.*—This line of section illustrates the structure of the area in the northern part of sheet 11 one-inch map, embracing portion of the Hermitage Water and Upper Liddisdale. It shows the ascending sequence from the Upper Old Red Sandstone ($c^3$) resting on the Silurian floor at Dinley Spout, through the Birrenswark volcanic zone ($d^i$) and the Whita sandstone ($d^{ii}$) to the Cementstone group ($d^{iii}$). On the west slope of Arnton Fell these subdivisions are faulted against the inlier of Upper Silurian strata on that ridge; while on its eastern side the sequence of the lower groups is again repeated in Upper Liddisdale; the higher part of the Cementstone group, with its marine limestones, being surmounted by the Fell sandstones ($d^{iv}$) and the Lawston coals ($d^{vi}$) on the Larriston Fells.

2. *Arkleton Fell to Caerby Hill and Kershope Burn.*—On the heights between the Ewes Water and the basin of the Liddel (Arkleton Fell and Cloak Knowe), the sequence from the Upper Old Red Sandstone to the Whita sandstone is exposed, the strata being there pierced by several necks of volcanic agglomerate and massive igneous rocks. Eastwards the members of the Cementstone group succeed, with which a sheet of basic lava is associated on Bedda Hill, till near Sorbietrees, south of New Castleton, they are overlaid by the Fell sandstones. On Caerby Hill these sandstones are capped by basic lava, probably representing the volcanic zone of Glencartholm, followed in turn by the Lawston Linn coals.

* The lamellibranchs from the rocks of the Canonbie coalfield have been examined by Dr Wheelton Hind, who is of opinion that they confirm the evidence obtained from the plant-remains that the strata in which they occur belong to the Coal-measures,—*Summary of Progress, Geological Survey for* 1902, p. 137.

3. *Ewes Water by Archerbeck to the Liddel Water.*—On the north-west slope of Whita Hill, east of Langholm, the unconformability at the base of the Upper Old Red Sandstone is well seen, as shown in section; the members of this formation being followed by the Birrenswark volcanic zone and the Whita sandstone. South-eastwards, towards the Tarras Water, the Cementstone group succeeds, excellent exposures of which are visible in the latter stream, overlaid in turn by the Fell sandstones ($d^{iv}$), the basic tuffs of the Glencartholm volcanic zone ($d^{v}$), and the beds on the horizon of the Lawston coals ($d^{vi}$). By means of a north and south fault on the moor between Tarras Water and Archerbeck, the two last groups are repeated as shown in section 3, followed by higher beds of the Marine Limestone series which stretch across the moorland to Archerbeck. In the latter stream, at a point about two miles above its junction with the Liddel, the arch of Lower Marine Limestones ($d^{vii}$) is truncated by a fault with a downthrow to the south (see section). On Harelaw Hill the massive Lower Marine Limestones again appear from underneath the beds on the horizon of the Kilnholm coals (Lickar position), and to the south-east at Penton Linns in the Liddel, as shown in section, the same limestones are exposed in sharp folds, being followed on the English side of the border by the thin Kilnholm coals, which are cut off by the great fault that throws down the red sandstones of the Upper Coal-measures ($d^{xiii}$).

4. *Wauchope Water by Glencartholm, Byre Burn, and Rowanburn to the Liddel Water.*—This section has been prepared to show the relations of the strata in the Esk below Langholm and in the Rowanburn coalfield, as proved by the mining plans. It is observable that the sequence from Langholm to Glencartholm is extremely clear, each group, from the Whita sandstone to the Glencartholm volcanic zone, with its fossiliferous shale, following each other in natural sequence. Between Glencartholm and the foot of Byre Burn the various subdivisions of the Marine Limestone series are met with, which are affected by numerous small faults and folds, most of which are omitted in the section. The small patch of Middle Coal-measures at Byre Burn is represented ($d^{xii}$), bounded on both sides by faults; but without the assistance of the fossil plants, the field geologist would hardly realise from the evidence on the ground that the Middle Coal-measures are there faulted, on the north-west side, against the higher part of the Marine Limestone series. The section further shows the gently inclined and faulted coal-seams of Rowanburn curving upwards, along the south-east margin near that colliery.

The remaining portion of this section is of special interest, as it shows the position of the great fault that bounds the Rowanburn coalfield on the south, the belt of Carboniferous red sandstone of the Upper Coal-measures ($d^{xiii}$) beyond, overlaid unconformably by the Triassic sandstones to the south.

5. *Birrenswark by Ecclefechan to the Kirtle Water.*—This line of section lies about twelve miles to the west of the river Esk, and furnishes important evidence of the great unconformability at the base of the Trias in that part of Dumfriesshire. From the slopes of Birrenswark the basic lavas dip gently southwards, followed by the Whita

sandstone, the Cementstone group, and by the Fell sandstones, which form a conspicuous eminence at Brownmoor Wood ($d^{iv}$). These, in turn, are overlaid by the members of the Marine Limestone series, which occupy the area southwards to the margin of the Trias. At Kirtlebridge the limestones of the Lower Limestone group (Penton Linns and Gilnockie) are exposed in various quarries, where they have been extensively worked. Their outcrops show that the beds were folded in arches and troughs before the deposition of the Trias, for the latter rests on the upturned and denuded edges of the members of the Marine Limestone series (see section 5). It is obvious, therefore, that in pre-Triassic time there must have been prolonged denudation of the Carboniferous rocks in that region; for all the divisions of the Canonbie Coal-measures were removed, and the Marine limestones underneath the Kilnholm coals were laid bare before the Triassic sandstones were deposited.

Similar evidence is obtained in the Cadgill Burn, a tributary of the river Sark, about half-way between Canonbie and Kirtlebridge. In that stream, within a few yards of the margin of the Trias, there is a band of stained limestone, charged with encrinite stems, *Euomphalus carbonarius*, *Bellerophon*, *Machrochilina*, and indeterminable fragments of brachiopods, with stained sandstone containing modioliform shells. Here again the Triassic sandstone rests on the upturned and denuded edges of the Marine limestones, and the Coal-measures have been removed.

Westwards beyond the Annan, at Kelhead and Clarencefield, the limestones of this horizon appear. Much of that district is thickly covered with drift, but at the latter locality the Marine limestone occurs within a mile of the margin of the New Red Sandstone, which points to transgression of the Trias and the removal by denudation of the Coal-measures.

## IV. Estimate of Coal-supply in Concealed Coalfield underlying the Red Sandstones of the Upper Coal-measures, North of the Triassic Rocks at Canonbie.

In the previous sections of this paper descriptive of the subdivisions of the Coal-measures, the evidence has been given which leads to the conclusion that the Middle Coal-measures of Byre Burn and the Lower Coal-measures of Rowanburn lie underneath the Carboniferous red sandstones ($d^{xiii}$). It was further stated that the area covered by the latter amounts to two square miles.

We have prepared the following estimate of the coal-supply of this concealed coalfield on the basis that a seam of coal one foot thick and one square mile in area contains 900,000 tons of coal:—

| | |
|---|---|
| Rowanburn Coals, estimated thickness 38 feet, . . | 68,400,000 tons. |
| Byre Burn Coals, estimated thickness 6 feet, . . | 10,800,000 tons. |

An important economic question arises as to the probability of finding workable coal-seams in the Carboniferous area north of the Triassic rocks between Canonbie and the river Nith below Dumfries. In the previous section (p. 866) evidence has been given to prove that in the tract extending from the river Sark by Kirtlebridge, westwards to Clarencefield, near the mouth of the Nith, the three divisions of the Coal-measures at Canonbie were removed by denudation before the Triassic rocks were deposited. There is therefore no prospect of finding any part of the Coal-measures within that area north of the Trias. The same evidence renders it very improbable that the Coal-measures will be found underneath the Trias extending from the Cadgill Burn near Kirkpatrick south-westwards to Annan, or below the basin of New Red Sandstone at Dumfries.

Bores have been put down near Springkell, east of Kirtlebridge, which have proved the existence there of thin coal-seams, but none workable. This result is what might be expected from a consideration of the evidence in the field, for these thin seams lie there below the Marine limestones of Kirtlebridge ($d^{vii}$, Plate III.), on the horizon of the Lawston Linn coals of Liddisdale and the Scremerston coals of Northumberland ($d^{vi}$, Pl. III.). These coals, as developed in Dumfriesshire, are of little or no economic importance. It is probable, however, that representatives of the Kilnholm coals ($d^{viii}$, Pl. III.) might be found underneath the Trias between Cadgill Burn and Annan, but even these seams, as they appear in Liddisdale, are too thin to be worked at the present time.

## V. Comparison of the Carboniferous Subdivisions in Eskdale and Liddisdale with those in Northumberland and Central Scotland.

The evidence relating to the correlation of the Carboniferous subdivisions in Eskdale and Liddisdale with those in Northumberland is fortunately of a conclusive character. To Mr Tate, of Alnwick, belongs the merit of having been the first to establish the sequence of the Carboniferous rocks in north Northumberland, where he worked it out between 1849 and 1868. His classification is given below :—

3. Calcareous group, embracing all the beds from the base of the Millstone Grit down to the Dun Limestone, and containing numerous marine limestones, with alternations of sandstones, shales, and coal-seams.
2. Carbonaceous group, with various workable coal-seams (Scremerston coals) and thin limestones, usually impure.
1. Tuedian group, comprising all the strata between the base of the Carbonaceous division and the Upper Old Red Sandstone, and containing shales, clays, sandstones, and thin beds of argillaceous limestone (Cementstone group).

This classification has been adopted by the Geological Survey with one modification, viz., the insertion of the Fell Sandstone group between the Tuedian and Carbonaceous divisions. The detailed mapping of the border territory has shown

that TATE's classification applies not only to north Northumberland, but to north-east Cumberland, Liddisdale, and Eskdale.

The foregoing order of succession is exposed in clear sections in the basin of the Tweed near Berwick, and along the shore to the south-east of that town as far as Cheswick, which we had an opportunity of examining this year.

The conformable passage from the Upper Old Red Sandstone through the contemporaneous volcanic rocks of Kelso, which at Carham are overlain by a prominent band of cornstone, into the overlying Cementstone group, is well seen in various streams, as for instance in the tributary of the Whiteadder near Preston, west of Edrom. Throughout the Merse of Berwickshire there is an extensive development of the Cementstone group, where they consist of green, grey, and red shales and clays, sandstones, and pale argillaceous limestones and cementstones, which, save on certain horizons, rarely yield fossils. Plant remains occur in some of the beds, but there are no coal-seams. No limestones, similar to those at Larriston and Thorlieshope in Liddisdale, with corals, brachiopods, and other organic remains indicating open sea conditions, have yet been found in the Cementstone group in the Merse. The fauna is largely estuarine, the characteristic form being *Modiola Macadami*. In the higher part of the group in the Tweed, near Coldstream, lamellibranch limestones, with *Orthoceras*, *Pleurotomaria*, fish-remains, scorpions, and crustaceans occur. Similar evidence is obtained at the head of Redesdale, where one of the limestone bands near the top of the group is richly charged with lamellibranchs, together with *Orthoceras* and *Rhynchonella*.*

The district south of the Tweed from Norham and Berwick, south by Lowick to beyond Belford, was accurately mapped and described by our late colleague Mr GUNN, where the order of succession is remarkably clear. On the slope overlooking the Tweed between Norham and Berwick, the Cementstone group is surmounted by the Fell sandstones, which in the north-east part of that area reach a thickness of 300 feet, but gradually swell out towards the south-west to 600 feet. Next in order come the members of the Carbonaceous group (Scremerston coals), with several workable coal-seams, the outcrops of which are laid down on the Geological Survey maps (sheets 110, N.W., N.E., old series, England and Wales). The average thickness of this division was estimated by Mr GUNN at 800 feet.†

The Scremerston coals and associated strata are followed in normal sequence by the Calcareous division, which, according to TATE'S classification, as already indicated, embraces all the beds from the base of the Dun Limestone to the base of the Millstone Grit. The Calcareous division has been further classified into a Lower Calcareous subgroup, including the beds from the base of the Dun Limestone to the top of the Dryburn Limestone (1480 feet),‡ and an Upper Calcareous subgroup comprising the

* *Mem. Geol. Surv.*,—Geology of the Country round Otterburn and Elsdon, p. 10.
† *Ibid.*, Geology of the Coast south of Berwick-on-Tweed, p. 4.
‡ *Ibid.*, p. 17.

strata from the top of the Dryburn limestone to the base of the Millstone Grit (600 feet). At the base of the Upper Calcareous subgroup lie the Lickar coals (see Pl. IV.).

On the shore from Spittal, south-east to Cheswick, at low water, there are tolerably continuous sections of the Lower Calcareous subgroup, where the individual bands may be studied to advantage. The characteristic feature of the group is the presence of marine limestones, charged with corals, brachiopods, gasteropods, and other organic remains, indicating true marine conditions. In the lower portion there are three marked beds of limestone, the Dun, the Woodend, and the Oxford (see Pl. IV.), with sandstones, shales, thin seams of coal, and a band of oil-shale. In the upper part of this subgroup the marine limestones appear in force, which are here given in descending order, with the local names given to them at Lowick.*

| | | | |
|---|---|---|---|
| No. 1 | Limestone | (Dryburn) . . . . | 25 feet. |
| ,, 2 | ,, | (Low Dean) . . . . | |
| ,, 3 | ,, | (Acre) . . . . | 20 ,, |
| ,, 4 | ,, | (Eelwell) . . . . | 20 ,, |

Sandstones, shales, and thin coal-seams are associated with these limestones; the highest (No. 1) being eventually succeeded at Cheswick by the Lickar Main coal, which was formerly wrought at that locality.

Our late colleague Mr Gunn states in his valuable paper on "The Correlation of the Lower Carboniferous Rocks of England and Scotland," that these four limestones (Nos. 1 to 4) have been traced almost continuously for nearly 100 miles in the northern counties of England, under various local names, so that there can be no doubt as to the identity of the limestones.†

At Lickar, about one mile north of Lowick, a small group of coals (the Lickar coals) succeeds the Dryburn limestone, embracing three and in some sections four seams, which seem to be inconstant.‡ These, in descending order, are the Limestone coal, Parrot coal, Rough coal, and Main coal.

South of Alnwick, towards Shilbottle and Felton, on the river Coquet, the representative of the Dryburn limestone is followed by the Upper Calcareous subgroup, including several limestones, the highest of which, laid down on the Geological Survey map (sheet 109, S.W., old series), is the Fell Top band. This subdivision is followed towards the east by the Millstone Grit and the Coal-measures.

The evidence now adduced shows clearly the striking resemblance between the sequence of the Lower Carboniferous rocks in Northumberland and that in Eskdale and Liddisdale, which is represented in graphic form in the vertical sections in Pl. IV. Apart from the resemblance in the successive groups, the correlation is further strengthened by the fact that some of the subdivisions have been traced more or less continuously from the one region to the other. For example, if we exclude the area in

* *Mem. Geol. Sur.*,—Geology of Coast south of Berwick-on-Tweed, p. 16.

† *Trans. Edin. Geol. Soc.*, vol. vii. p. 365.

‡ *Mem. Geol. Sur.*,—Geology of Belford, Holy Island, and the Farne Islands, p. 39.

the Cheviots occupied by the Lower Old Red Sandstone volcanic rocks, the Fell sandstones extend from Tweedmouth, by Carter Fell and across Dumfriesshire, to the mouth of the Nith. In like manner the group of Scremerston coals has been traced from the shore to the Old Red volcanic platform of the Cheviots, and reappears at Lewisburn in the basin of the Rede Water, Northumberland, where, as Mr Clough * has shown, they overlie the mass of the sandstones of Peel Fell, and come beneath the coal-seams of the Plashetts. The Lewisburn coals cross over into the upper part of the Kershope Water and into the head of Tweeden Burn, and appear in Scotland as the Muirburn and Lawston Linn coals.

It is obvious, therefore, that the Calcareous division of Northumberland, with its dominant bands of marine limestone, are the equivalents of the Calcareous series which in Liddisdale and Eskdale overlie the Lawston Linn and the Muir Burn coals. We may reasonably proceed one step further and suggest that the massive marine limestones at Lowick, Northumberland, including the Dryburn, Low Dean, Acre and Eelwell bands, may be wholly or partly represented by the limestones of Penton Linns, Harelaw Hill and Gilnockie in Liddisdale. But while there is doubtless a striking general resemblance in lithological and palæontological characters in the Lower Carboniferous rocks of these two areas, pointing to similar terrestrial movements along the margin of the old Silurian tableland, yet there are some specific distinctions worthy of note. It has been shown that even below the Fell sandstones, in the upper part of the Cementstone group in Liddisdale, marine limestones appear charged with crinoids, corals, brachiopods, gasteropods and other organisms which have not been found in the same group in Berwickshire nor in Northumberland—a fauna, indeed, which is characteristic of the Carboniferous Limestone series. It further appears that the Scremerston coals, which comprise several workable seams south of the Tweed, gradually diminish in number and dwindle in importance when traced south-westwards into Dumfriesshire. The same observation applies to the Lickar coals.

Proceeding now to the consideration of the Carboniferous subdivisions in the Lothians and Fife, we meet with certain marked divergencies from the types of sedimentation in the border territory. Nevertheless it is possible to correlate the main divisions. A glance at the vertical sections of the Carboniferous system in Edinburgh and Fife shows how the sequence varies according to the special districts in which they are taken. For our present purpose it will be sufficient if we indicate the general characters of these divisions, and their equivalents in the border territory.

In central Scotland the Lower Carboniferous rocks are grouped in two divisions: (1) The Calciferous Sandstone series, overlain by (2) the Carboniferous Limestone series. The former is subdivided into (*a*) the Cementstone group, consisting of green, gray and red shales and clays, sandstones of various tints with pale argillaceous limestones or cementstones, which, like their equivalents in Berwickshire and Dumfriesshire, are singularly barren of organic remains, save on certain horizons; and (*b*) the oil shale

* *Mem. Geol. Sur.*, "The Geology of Plashetts and Kielder," p. 36.

group, composed of gray, white and yellow sandstones, black and blue shales, oil-shales, occasional thin coal-seams, clay ironstones, and thin limestones. The palæontological researches of Dr Traquair, Mr R. Etheridge, jun., the late Mr Kirkby, and others, have shown that while the fauna points mainly to estuarine or brackish water conditions, there are marine bands particularly in Midlothian and the east of Fife which increase in number near the top of the group as we approach the base of the Carboniferous limestone series. Indeed, Mr Kirkby has shown that the fauna of the Carboniferous limestone is present in the upper part of the Calciferous Sandstone series, so that the boundary line between these two divisions is merely an arbitrary one.

The normal Cementstone group appears to the north of the Silurian tableland, on the shore at Cockburnspath, where it rests comformably on the cornstone zone of the Upper Old Red Sandstone, the latter yielding scales of *Holoptychius nobilissimus*. The Cementstones there, as shown by Mr Clough,* are of no great thickness, being truncated by a fault bringing in a subgroup of shales, sandstones, fireclays and thin coals (the latter under one foot thick), which probably represent the Scremerston division of Northumberland. Though on the whole unfossiliferous, the Cementstones there contain a brecciated lamellibranch limestone with plant remains, which recalls similar types in this group in the border region and in the Randerston beds in Fife, to which attention will be immediately directed. Overlying the Carbonaceous group on the shore at Cove, near Cockburnspath, we find sandstones, shales, two thin marine crinoidal limestones, clays, and a thin oil shale.† The late Mr Gunn suggested that the group of the Dun and Woodend limestones might be represented by the marine limestones in Cove Harbour, and that the oil-shale might be the equivalent of that beneath the Oxford limestone.‡ But whether this be correct or not, there can be no doubt that the Cove oil-shale represents a stage of the oil-shale group of the Lothians. Unfortunately there is no continuous section from the beds just described up to the marine limestones at Longcraig, Skateraw, and Chapel Point, at the base of the Carboniferous Limestone series, east of Dunbar, but the section so far is a connecting link between the Carboniferous subdivisions of the border region and central Scotland.

In Midlothian the normal Cementstones appear underneath the volcanic platform of Arthur's Seat, and overlying the Upper Old Red Sandstone in the southern part of Edinburgh. From a recent exposure in the city of Edinburgh, the remains of plants, ostracods, worms, crustaceans and fishes were obtained. The late Mr Kirkby stated, as the result of his examination of the ostracods from this section, that had "the lot been found in Fife it would not have been higher than the Billow Ness beds." (See Plate IV.)

Above the volcanic platform of Arthur's Seat comes the great succession of strata ranging from the Granton sandstone and Wardie shales to the Hurlet limestone, the

* *Geol. Survey, Sum. of Progress for* 1902, p. 121. † *Ibid.*
‡ *Trans. Edin. Geol. Soc.*, vol. vii. p. 366.

total thickness of strata amounting to about 3650 feet. No workable oil-shales occur in the lowest part of this group till we reach the level of 800 feet beneath the Burdiehouse Limestone, which is the position of the Pumpherston band. According to Mr Cadell's computations the oil-shales appear on different horizons in a series of strata whose vertical thickness is about 2750 feet, the highest band being the Raeburn shale, about 450 feet beneath the Hurlet limestone.*

It is obvious, therefore, that the oil-shale group as developed in Midlothian differs in a marked degree from the higher part of the Calciferous Sandstone series found in East Lothian.

In East Fife the Calciferous Sandstone series has an exceptional development, with special lithological and palæontological characters, which have been admirably described by Sir A. Geikie in his recent memoir on "The Geology of East Fife."† He calls attention to the fact that in place of the widely separated marine platforms, with comparatively few fossils, to be found in the Lothians and Western Fife, there is a great succession of marine bands crowded with organic remains, and alternating with numerous coal-seams, which distinguishes the group in the East of Fife from any other equivalent strata in Scotland, the total thickness amounting to about 4500 feet.

Below the sandstones of Fife Ness, as Sir A. Geikie has pointed out, there emerges a group of shales, clays, and thin seams of cementstone, resembling the Cementstone group in other parts of Scotland.‡ This group passes downwards into a nodular cornstone, which may represent the band at the top of the Upper Old Red Sandstone. Next in order come the Randerstone beds, composed of alternations of *Spirorbis* and lamellibranch limestones, sandstones, shales, with occasional fireclays, root beds and thin coals. No purely marine bands occur in this estuarine subdivision, though such marine organisms as *Bellerophon*, *Rhynchonella* and *Orthoceras* are met with. These are overlaid by the Billowness sandstones, followed by alternations of impure oil-shales, sandstones, cyprid limestones, with nineteen thin coals, and eventually by the "Encrinite bed," which forms a marked horizon in the Calciferous Sandstone of East Fife. This impure limestone is charged with corals, crinoids, polyzoa, brachiopods, including four species of *Productus*, a fauna which is characteristic of the Carboniferous Limestone series. Above the Encrinite limestone comes a succession of sandstones, shales, ironstones and thin coals, near the top of which there are bands of limestone (Abden limestones), which contain a typical marine fauna like that of the Hurlet and Hosies limestones.

It is obvious that in the Calciferous Sandstone of the East of Fife there is a striking departure from the type of strata which in Northumberland intervenes between the Fell sandstones and the Eelwell limestone. It is not improbable that the "Encrinite bed" of Fife may be the equivalent of the crinoidal limestone at Cove, near Cockburnspath.

In central Scotland the Carboniferous Limestone series, as is well known, is represented by a lower group containing marine limestones, sandstones, shales, fireclays and

* *Trans. Geol. Soc. Edin.*, vol. viii., part i., p. 136.

† *Memoirs of the Geol. Survey*, "The Geology of East Fife," 1902, p. 71. ‡ *Ibid.*, p. 121.

occasional coal-seams; a middle group (Edge Coals), consisting of many valuable coal seams, ironstones, sandstones and shales, with no limestones; and an upper group, composed of limestones, sandstones, shales and coal-seams. This triple classification obtains throughout the midland valley, the lithological and palæontological types being remarkably persistent.

The lower group of limestones (Hurlet and Hosies) has been correlated by the late Mr Gunn with the massive marine limestones at Lowick,* Northumberland (Dryburn, Low Dean, Acre and Eelwell), which, as already indicated, are separated from the upper limestone group by the Lickar Coals. (See Plate IV.) If this correlation, which is highly probable, should ultimately prove to be correct, then it follows that the group of strata which, in Northumberland and Eskdale, intervene between the base of the Fell sandstones and the Eelwell and Gilnockie limestones, represents that part of the Calciferous Sandstone in central Scotland which overlies the Cementstone group. It may be further noted that the Lickar and Kilnholm coals are meagre representatives of the valuable series of Edge Coals in the midland valley. (See Plate IV.)

The triple classification of the Coal-measures at Canonbie adopted by Mr Kidston, from the evidence of the plants, does not obtain in central Scotland. In the latter area only the Lower and Middle Coal-measures are represented: the lower group containing a valuable series of coals and ironstones, and the middle consisting of red sandstones, shales, clays, marls, thin limestones, and poor coals, yielding plants, molluscs, crustaceans and fishes. On the evidence of the plants Mr Kidston correlates this Red Sandstone group, like that of Byre Burn at Canonbie, with the middle Coal-measures of England.†

---

List of Papers Referring to the Geology of the Districts under Review.

1844. Milne Hume, "Geological Account of Roxburghshire," *Trans. Roy. Soc. Edin.*, vol. xv. p. 433.

1853. Tate, G., "The Fossil Flora of the Mountain Limestone Formation of the Eastern Borders," in *Johnstone's Nat. Hist. of the Eastern Borders*, p. 290.

1857. Tate, G., "Anniversary Address to the Members of the Berwickshire Naturalists' Club," *Proc. Berwickshire Nats. Club*, vol. iii. p. 135. (Read 1853.)

1857. Embleton, R., "Address delivered to the Berwickshire Naturalists' Club," *Proc. Berwickshire Nats. Club*, vol. iii. p. 219. (Read 1856.)

1861. Howell, H. H., and (Sir) A. Geikie, *Memoir of Geological Survey of Great Britain*, "Geology of the Neighbourhood of Edinburgh" (sheet 32).

1862. Gibsone, E., "The Coal Formation of Canonbie," *Trans. North of England Institute of Mining Engineers*, vol. xi. p. 65.

---

* *Trans. Geol. Soc. Edin.*, vol. vii. p. 306.

† We wish to acknowledge the valuable assistance rendered by Mr A. Macconochie and Mr D. Tait in the preparation of the fossil lists embodied in this paper and the list of papers referring to the geology of the districts under review.

1863. Geikie, A., *Memoir of Geological Survey of Great Britain*, "The Geology of Eastern Berwickshire" (sheet 34).

1863. Tate, G., "Fauna of the Mountain Limestone on the Berwickshire Coast, with a preliminary notice of the succession of the strata on the Eastern Borders," *Proc. Berwickshire Nats. Club*, vol. iv. p. 151.

1864. Binney, E. W., "Observations on the Carboniferous, Permian, and Triassic Strata of Cumberland and Dumfries," *Proc. Lit. and Phil. Soc. Manchester*, vol. iii. p. 162.

1865. Binney, E. W., "Further Observations on the Carboniferous, Permian, and Triassic Strata of Cumberland and Dumfries," *Mem. Lit. and Phil. Soc. Manchester*, series 3, vol. ii. p. 343. (Read October 1863.)

1866. Geikie, (Sir) A., H. H. Howell., and J. Young., *Memoir Geological Survey of Great Britain*, "The Geology of East Lothian" (sheets 33, 34, 41).

1868. Bailes, G., "Sections of Mountain Limestone Strata at Scremerston, Northumberland, with a 'Note on the Scremerston Sections,' by G. Tate," *Proc. Berwick Nat. Field Club*, vol. v. p. 349.

1868. Tate, G., "Miscellanea Geologica for 1866," *Proc. Berwickshire Nats. Club*, vol. v. p. 283.

1869. Tate, G., "The Geology, Botany, and Zoology of the Neighbourhood of Alnwick," 8vo, Alnwick. (Reprint of chapters from the History.)

1874. Goodchild, J. G., "Note on the Carboniferous Conglomerates of the Eastern Part of the Basin of the Eden," *Quart. Jour. Geol. Soc.*, vol. xxx. p. 394.

1875. Lebour, G. A., "On the Limits of the Yoredale Series in the North of England," *Geol. Mag.*, Dec. 2, vol. ii. p. 539.

1876. Lebour, G. A., "On the Larger Divisions of the Carboniferous System in Northumberland," *Trans. North of England Institute Mining Engineers*, vol. xxv. p. 225.

1877. Binney, E. W., "Note on the Upper Coal Measures, Canonbie," *Proc. Lit. and Phil. Soc. Manchester*, vol. xvi. p. 192.

1878. Etheridge, R., jun., "The Invertebrate Fauna of the Lower Carboniferous or Calciferous Sandstone Series of the Edinburgh Neighbourhood." (Read November 7, 1877.) *Quart. Jour. Geol. Soc.*, vol. xxxiv. pp. 1–26.

1878. Lebour, G. A., Geological Map of Northumberland.

1878. Lebour, G. A., *Outlines of the Geology of Northumberland*, 8vo, Newcastle (2nd ed. in 1886).

1879. Geikie, (Sir) A., J. Geikie, and B. N. Peach., *Mem. Geol. Sur. Scot.* (sheet 31).

1881. Geikie, (Sir) A., "A Recent 'Find' in British Palæontology," *Nature*, vol. xxv. p. 1.

1883. Peach, B. N., "On some New Crustaceans from the Lower Carboniferous Rocks of Eskdale and Liddisdale," *Trans. Roy. Soc. Edin.*, vol. xxx. p. 73. (Read July 1880.)

1883. Peach, B. N., "On some New Species of Fossil Scorpions from the Carboniferous Rocks of Scotland and the English Border," *Trans. Roy. Soc. Edin.*, vol. xxx. p. 397. (Read June 1881.)

1883. Peach, B. N., Further Researches among the Crustacea and Arachnida of the Carboniferous Rocks of the Scottish Border," *Trans. Roy. Soc. Edin.*, vol. xxx. p. 511. (Read March 1882.)

1883. Traquair, R. H., "Report on Fossil Fishes collected by the Geological Survey of Scotland in Eskdale and Liddisdale," *Trans. Roy. Soc. Edin.*, vol. xxx. p. 15. (Read July 1880.)

1883. Kidston, Robert, "Report on Fossil Plants, collected by the Geological Survey of Scotland, in Eskdale and Liddisdale," *Trans. Roy. Soc. Edin.*, vol. xxx. p. 531. (Read March 1882.)

1884. Traquair, R. H., "Description of a Fossil Shark (*Ctenacanthus costellatus*) from the Lower Carboniferous Rocks of Eskdale, Dumfriesshire," *Geol. Mag.*, Dec. 3, vol. i. p. 1.

1884. Traquair, R. H., "Remarks on the Genus *Megalichthys*, with description of a new Species," *Geol. Mag.* (3), vol. i. pp. 115–121, Plate V. (At p. 121, Dr Traquair remarks that, as the result of his experience in the Domain of British Carboniferous Ichthyology, "very few species of Ganoids are common to the Strata above and below the Millstone Grit.")

1887. Lebour, G. A., "Sketch of the Geology of Northumberland," *Proc. Geol. Assoc.*, vol. ix. p. 555.

1887. Miller, Hugh, *Mems. Geol. Survey England and Wales*, "The Geology of the Country round Otterburn and Elsdon" (explanation of quarter sheet 108 S.E., new series, sheet 8).

1887. Miller, H., "On the Classification of the Carboniferous Limestone Series; Northumberland Type," *Rep. Brit. Assoc.* for 1886, p. 674.

1888. Howse, R., "Contributions towards a Catalogue of the Flora of the Carboniferous System of Northumberland and Durham, Part I.," *Trans. Nat. Hist. Soc. Northumberland*, vol. x. p. 19.

1888. Clough, C. T., "The Geology of the Cheviot Hills (English side)" (explanation of quarter sheet 108 N.E., new series, sheet 5).

1888. Brown, M. W., "A further attempt for the Correlation of the Coal-seams of the Carboniferous Formation of the north of England, with some notes on the probable duration of the Coalfield," *Trans. N. of England Inst. Min. Engrs.*, vol. xxxvii. p. 3.

1889. Goodchild, J. G., "Programme of the long excursion to N.W. Cumberland and the Eden Valley," *Proc. Geologists' Assoc.*, p. 34, and "Report on the Excursion," p. xciv.

1889. Clough, C. T., *Mem. Geol. Sur. of England and Wales*, "The Geology of Plashetts and Kielder" (explanation of quarter sheet 108 S.W., new series, sheet 7).

1890. Traquair, R. H., "Observations on some Fossil Fishes from the Lower Carboniferous Rocks of Eskdale, Dumfriesshire," *Ann. and Mag. Nat. Hist.*, vol. vi., 6th series, p. 492.

1890. Traquair, R. H., "List of the Fossil Dipnoi and Ganoidei of Fife and the Lothians," *Proc. Roy. Soc. Edin.*, vol. xvii. pp. 385–400.

1892. Goodchild, J. G., "The Limestones of Cumberland and Westmoreland," *Trans. Cumb. and Westm. Assoc. for Adv. of Lit. and Science*, vol. xvi. p. 145.

1894. Kidston, R., Presidential Address, "On the various divisions of British Carboniferous Rocks, as determined by their Fossil Flora," *Proc. Roy. Phys. Soc. Edin.*, vol. xii. pp. 183–257 (Canonbie, p. 200).

1895. Gunn, W., and C. T. Clough, *Mem. Geol. Sur. of England and Wales*, "The Geology of part of Northumberland, including the country between Wooler and Coldstream" (explanation of quarter sheet 110 S.W., new series, sheet 3).

1897. Gunn, W., *Mem. Geol. Sur. of England and Wales*, "The Geology of the Coast south of Berwick-on-Tweed" (explanation of quarter sheet 110 N.E., new series, sheet 2).

1897. Goodchild, J. G., "An Outline of the Geological History of the Rocks around Edinburgh," *Proc. Geol. Assoc.*, vol. xv. pp. 117–143 and 200–5.

1897. Hind, Wheelton, "On the Subdivisions of the Carboniferous Series in Great Britain, and the true position of the beds mapped as the Yoredale Series," *Geol. Mag.*, Dec. 4, vol. iv. pp. 159–69 and 205–13.

1898. Hind, Wheelton, "The subdivisions of the Carboniferous Series in Great Britain and some of their European equivalents," *Trans. Edin. Geol. Soc.*, vol. vii. p. 332.

1898. Jones, T. R., J. W. Kirkby, and Dr J. Young, "On Carbonia, its horizons and conditions of occurrence in Scotland, especially in Fife," *Trans. Edin. Geol. Soc.*, vol. vii. p. 420.

1898. Gunn, W., "Notes on the Correlation of the Lower Carboniferous Rocks of England and Scotland," *Trans. Edin. Geol. Soc.*, vol. vii. p. 361.

1900. Gunn, W., *Mem. Geol. Survey of England and Wales*, "The Geology of Belford, Holy Island, and the Farne Islands, Northumberland" (explanation of quarter sheet, 110 S.E., new series, sheet 4).

1900. Geikie, Sir A., *Mem. Geol. Sur. of Scotland*, "The Geology of Central and Western Fife and Kinross" (sheet 40).

1901. Cadell, H. M., "The Geology of the Oil Shalefields of the Lothians," *Trans. Edin. Geol. Soc.*, vol. viii. p. 116.

1901. Goodchild, J. G., "The Victoria County Histories, Cumberland," *The Geological History of Cumberland*, pp. 1–64.

1901. Traquair, R. H., "Notes on the Lower Carboniferous Fishes of Eastern Fifeshire," *Geol. Mag.* (4) vol. viii. pp. 110–114.

1902. Geikie, Sir A., *Mem. Geol. Sur. Scotland*, "The Geology of Eastern Fife" (sheet 41).

1902. Hind, Wheelton, "On the Characters of the Carboniferous Rocks of the Pennine System," *Proc. Yorkshire Geol. and Polytechnic Soc.*, vol. xiv. p. 422.

1903. Gunn, W., *Mem. Geol. Sur. Scotland*, "The Geology of North Arran, South Bute, and the Cumbraes" (sheet 21, Scotland), chap. vi.

1903. Traquair, R. H., "On the Distribution of Fossil Fish-Remains in the Carboniferous Rocks of the Edinburgh District," *Trans. Roy. Soc. Edin.*, vol. xl. pp. 687–707.

1903. Kidston, R., "The Fossil Plants of the Canonbie Coalfield," *Summary of Progress of the Geological Survey of the United Kingdom for* 1902, p. 209.

1903. Goodchild, J. G., "The Lower Carboniferous Rocks of North Britain," *Trans. Glasg. Geol. Soc.*, vol. xii. p. 17.

1903. Goodchild, J. G., "The Geological History of Lower Tweedside," *Proc. Geologists' Assoc.*, vol. xviii. p. 105.

1903. Kidston, R., "The Fossil Plants of the Carboniferous Rocks of Canonbie and of parts of Cumberland and Northumberland," *Trans. Roy. Soc. Edin.*, vol. xl. pp. 741–833.

---

## DESCRIPTION OF PLATES.

### Plate I.

Geological map of the Canonbie District on the scale of two inches to a mile, showing the areas occupied by the Lower, Middle and Upper Coal-measures.

### Plate II.

Table of vertical sections prepared from journals of bores sunk in the Canonbie district.

Abbreviations:—Upper C.M = Upper Coal-measures; M.C.M. = Middle Coal-measures; L.C.M. = Lower Coal-measures; M.G. = Millstone Grit; C.L. = Carboniferous Limestone.

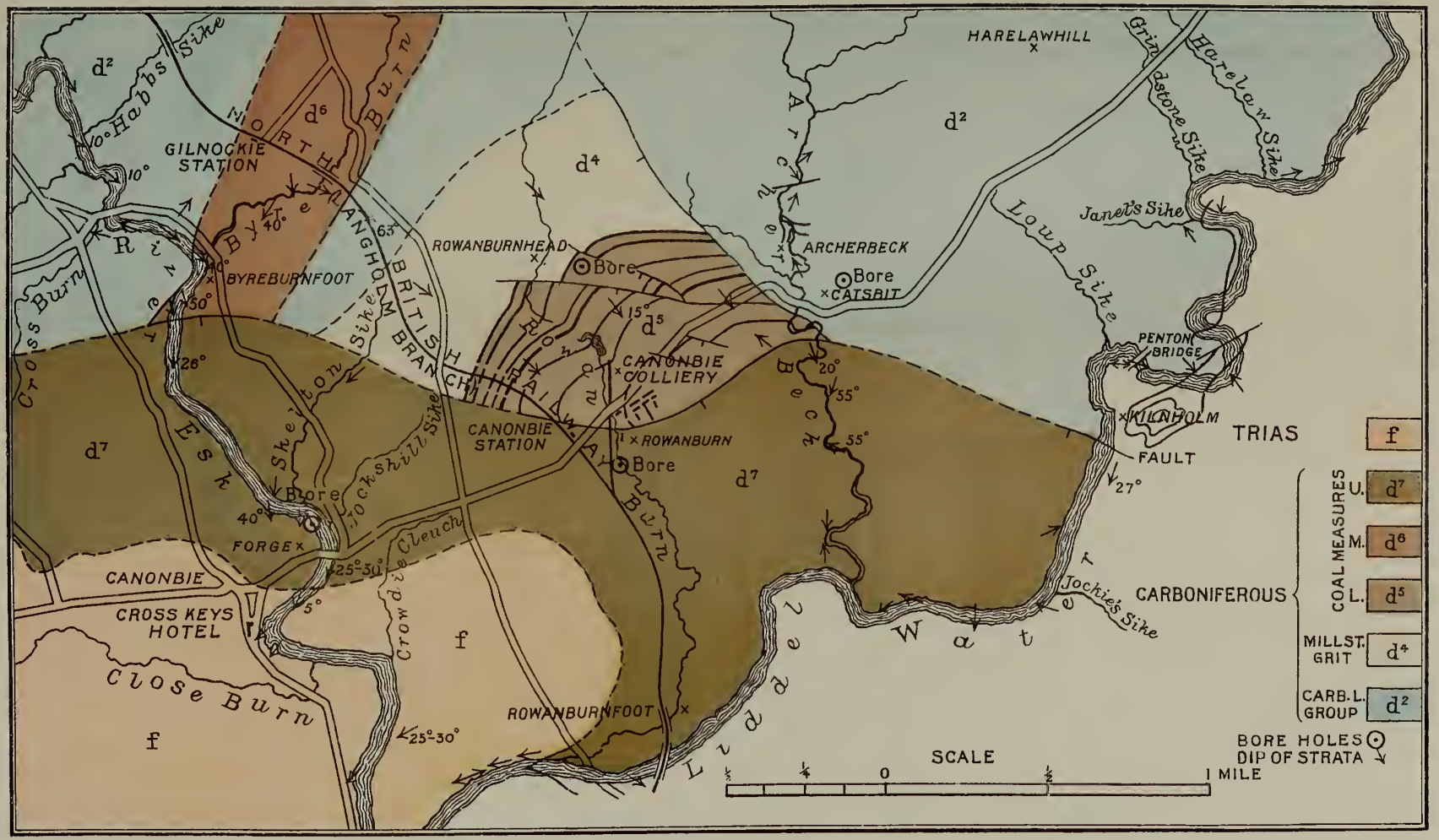
### Plate III.

Series of horizontal sections to illustrate the geological structure of the Border region between Liddisdale and Annandale.

Explanation of Geological Signs:—$b^5$ = Upper Silurian; $c^3$ = Upper Old Red Sandstone; $d^{i}$ = Volcanic Zone of Tarras Water and Birrenswark; $d^{ii}$ = Whita Sandstone; $d^{iii}$ = Cemenstone Group; $d^{iv}$ = Fell Sandstones; $d^{v}$ = Glencartholm Volcanic Group; $d^{vi}$ = Lawston Coals; $d^{vii}$ = Marine Limestones; $d^{viii}$ = Kilnholm Coals; $d^{ix}$ = Upper Limestones; $d^{x}$ = Millstone Grit; $d^{xi}$ = Rowanburn Coals; $d^{xii}$ = Byre Burn Coals; $d^{xiii}$ = Red Sandstones of Canonbie (Upper Coal-measures); $f$ = Trias.

### Plate IV.

Comparative series of vertical sections of the Carboniferous system in (1) Eskdale and Liddisdale; (2) Berwick and Northumberland; (3) Fife; (4) Midlothian.




M'Farlane & Erskine, Lith. Edin'

# COALFIELD (ROWAN BURN)

DEPTH IN FEET

## FORGE BORE.

U.C.M.

1000

COAL 7"
COAL 1'2"
COAL 2'5"
COAL 7"
COAL 9"
COAL 2'3"
1504 COAL 1'9"

## ROWAN BURN BORE.

U.C.M.

COAL 5"
COAL 6"
COAL 1'
COAL 5" — COAL 6"
COAL 1'8"
COAL 1'10" — COAL 1'2"
COAL 2'5" — COAL 1'6"
1579 MUSSEL-BAND

## BYRE BURN.

M.C.M.

MAIN COAL 4'10"
¾ COAL 3'
LIME COAL 4'
180

2000

## CANONBIE.

L.C.M.

COAL "UPPER" 3'4"
COAL "MAIN" 6'
COAL "SPLINT" 9'
COAL "THREE FEET" 2'8"
COAL "FIVE FEET" 5'6".
COAL "BLACK TOP" 4'9"
500 COAL "SEVEN FEET" 7'

3000

## ROWAN BURN HEAD BORE.

L.C.M.
M.G.
C.L.

COAL "SEVEN FEET"
COAL 9"
COAL 1'7" — COAL 1'5"
COAL 7" — COAL 1'3"
COAL 1'5"
COAL 1'8"
COAL 9"
600 COAL 9"
LIMESTONE 1'3"
LIMESTONE 10'
COAL 6"
LIMESTONE 20'
COAL 10" — COAL 4"
COAL 4" — COAL
COAL 2'4"
COAL "PARROT"
1344 COAL

4000

## CATSHIT BORE.

C.L.

COAL 4"
COAL 1'11"
COAL 5"
COAL "PARROT" 1'3"
COAL 7"
COAL 4"
LIMESTONE 3'
LIMESTONE & FAKES
LIMESTONE 70'
COAL
661 LIMESTONE 12'

4500

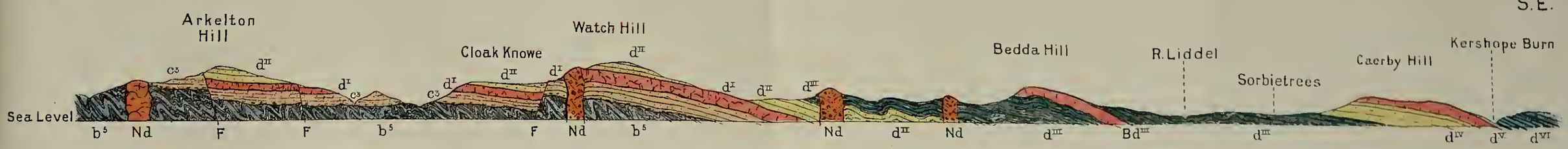
M'Farlane & Erskine, Lith. Edin.

Plate III.

N.W. S.E.

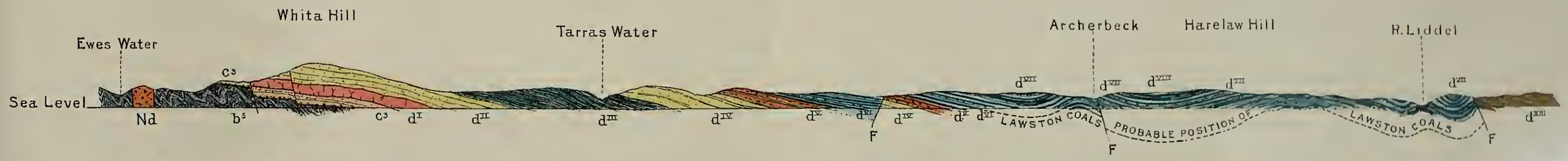

SECTION I

N.W. S.E.



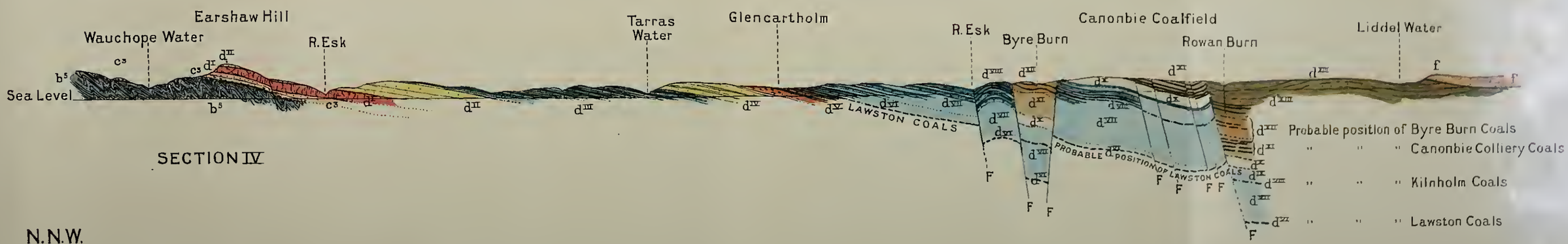

SECTION II

N.W. S.E.



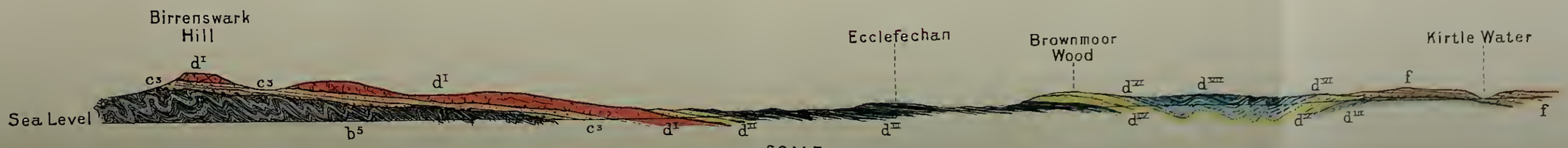

SECTION III

N.W. S.E.




SECTION IV

N.N.W. S.S.E.




SECTION V

SCALE

FEET 5000 4000 3000 2000 1000 0

1 2 MILES

M'Farlane & Erskine Lith. Edin.

## ESKDALE AND LIDDESDALE

## BERWICK AND NORTHUMBERLAND

## EAST FIFE

## MIDLOTHIAN

SCALE OF FEET 0 500 1000 2000 3000 4000 5000

CARBONIFEROUS

LOWER

UPPER

COAL-MEASURES

MILLSTONE GRIT

LOWER MIDDLE UPPER

dXIII Red Sandstone and Shales

Thin Coals

dXII "Byreburn" Coals

dXI "Rowanburn" Coals

Thin Coals and Sandstones

d X

dIX Upper Limestones

dVIII "Kilnholm" Coals

"Glinockie" Limestones and Thin Coals

dVII

"Lawston" and "Muirburn" Coals

dVI

Tuff
Scorpion Bed Oil Shale Tuff
"Olencartholm" Volcanic Group

dV

dIV Fells Sandstone

"Korshopefoot" Limestone

"Larriston" and "Thorlieshope" Limestones

Cementstone Group of Eskdale and Liddesdale

dIII

Whita Sandstone

dII

"Birrenswark" Volcanic Group

d I

Cornstone

c3 Upper Old Red Sandstone

Upper Limestones

"Lickar" Coals

"Dryburn" Limestone

"Lowdean" "

"Acre" "

"Eelwell" "

"Oxford" "

Oil Shale

"Woodend" Limestone

"Dun" "

"Scremerston" Coals

Fells Sandstones

Cementstone Group of the Merse

Cornstone

"Kelso" Volcanic Group

Upper Old Red Sandstone

Red Sandstones

"Dysart" and "Leven" Coalfield

"Castlecary" Limestone

"Cahny" or "Gair" Limestone

"Capledrae" Coals

"Index" Limestone

"Edge" Coals

"Hosles" Limestones

"Hurlet" Limestone

"Ablen" Limestones

Sandstones and Shales, with thin Coals, Ironstones, and Oil Shales

Fittenweem Sandstone

"Encrinite" Bed

Alternations of Sandstones and Shales with 19 thin Coal Seams and "Entomostracan" Limestones

Billowness Sandstones

Sandstones and Shales with Marine "Lamellibranch" Limestones. Anstruther and Randerstone Beds

Cornstone

Upper Old Red Sandstone

Red Sandstone Horizon not proved.

"Dalkeith" and "Musselburgh" Coalfield

Roslin Sandstones

No. 6 Limestone
No. 5 Limestone
"Wood" Coal

"South Parrot" Coal
No. 4 Limestone

"Edge" Coals

No. 3 Limestone
No. 2 "
No. 1 "

"Raeburn" Oil Shale
"Mungall" "
"Two Feet" Coal
"Houston" "

"Felle" Oil Shale

Broxburn Marls

"Broxburn" Oil Shale

Binary Sandstone

"Dunnet" Oil Shale

"Berracks" Oil Shale
"Burdiehouses" Limestone

"Pumpherston" Oil Shale

Hailes Sandstone

Wardie Shales

Granton Sandstone

Abbeyhill Shales

Arthur's Seat Volcanic Group

Cementstone Group or "Ballagan" Beds

Craigmillar Sandstones

Cornstone
Upper Old Red Sandstone

COAL-MEASURES MILLSTONE GRIT CARB. LIME. GROUP

CALCIFEROUS SANDSTONE SERIES